DOCUMENT RESUME

ED 410 411 CE 074 562

AUTHOR	Hilley, Robert
TITLE	General Electronics Technician: Digital Electronics and Introduction to Microprocessors.
INSTITUTION	Multistate Academic and Vocational Curriculum Consortium, Stillwater, OK.
PUB DATE	1997-00-00
NOTE	273p.; For related documents, see CE 074 560-561.
AVAILABLE FROM	Multistate Academic and Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074; World Wide Web: http://www.mavcc.org (teacher edition, order no. 800091: $23; student edition, order no. 800092: $12; 6 or more student editions: $6 each).
PUB TYPE	Guides - Classroom - Learner (051) -- Guides - Classroom - Teacher (052)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Career Education; Career Exploration; Career Guidance; Critical Thinking; Electric Circuits; Electricity; *Electronic Technicians; *Electronics; Electronics Industry; Laboratory Procedures; Laboratory Safety; *Learning Activities; Lesson Plans; *Microcomputers; Occupational Safety and Health; Postsecondary Education; Secondary Education; Shop Curriculum; Teaching Guides; Teaching Methods; Technological Advancement; *Technology Education; Thinking Skills; Units of Study; Vocational Education
IDENTIFIERS	*Digital Electronics

ABSTRACT

These instructional materials include a teacher's guide designed to assist instructors in organizing and presenting an introductory course in general electronics focusing on logic circuits and microprocessors and a student guide. The materials are based on the curriculum-alignment concept of first stating the objectives, developing instructional strategies for teaching those objectives, and then evaluating based on the objectives. The course contains two units, each designed for use in more than one class period: Logic Devices and Circuits and Introduction to Microprocessors. Each unit in the teacher edition includes some or all of the following: suggested activities, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, and transparency masters. In addition, the teacher edition includes a section on use of the publication, a competency profile, instructional and task analyses, academic and workplace skill classifications and definitions, a related academic and workplace skills list, and a correlation to the Electronics Industries Foundation skills list. Each of the instructional units in the student edition includes some or all of the following components of a unit of instruction: objective sheet, information sheet, assignment sheets, and job sheets. (KC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 410 411

General Electronics Technician
Digital Electronics and Introduction to Microprocessors

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

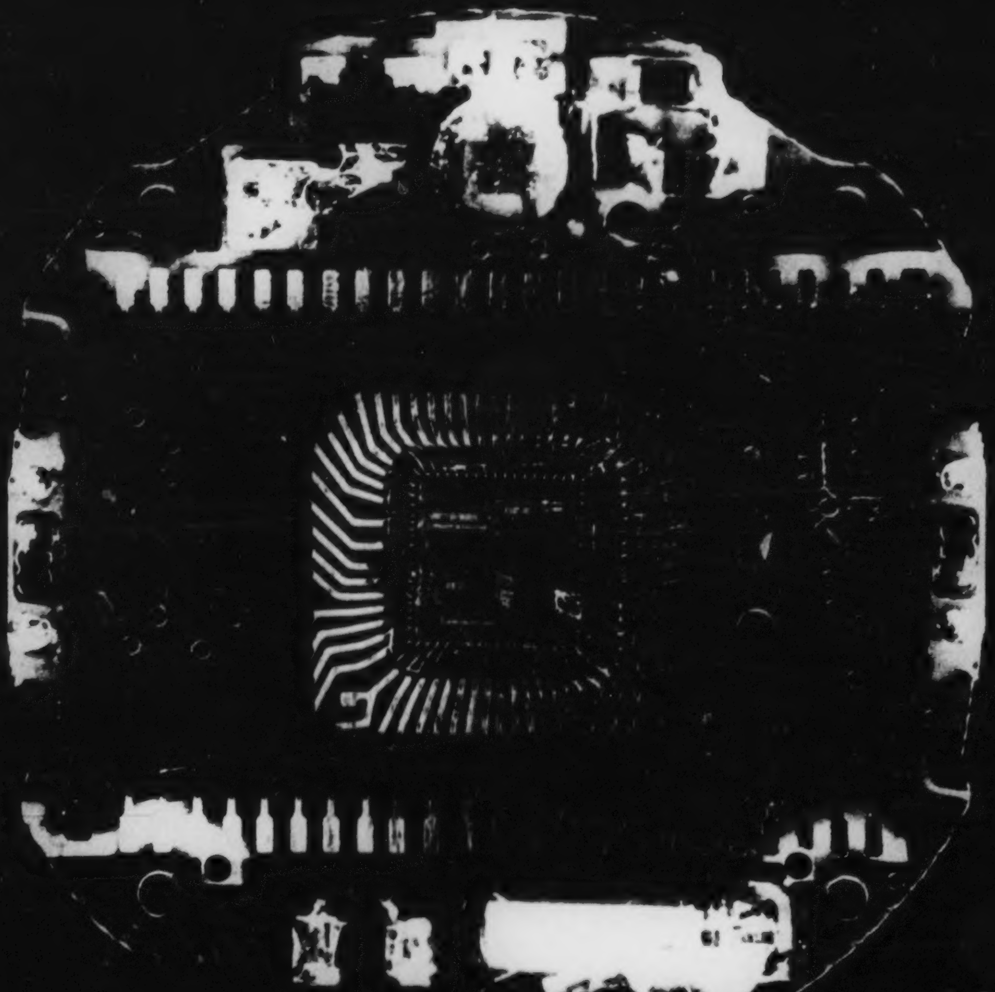
PERMISSION TO REPRODUCE AND
DISSEMINATE THIS MATERIAL
IN OTHER THAN PAPER COPY
HAS BEEN GRANTED BY

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)

CE 074 562

BEST COPY AVAILABLE

General Electronics Technician: Digital Electronics and Introduction to Microprocessors



Teacher Edition

MAVCC

BEST COPY AVAILABLE

General Electronics Technician:

Digital Electronics and Introduction to Microprocessors

Written by

Robert Hilley, Technical Writer

Project coordinated by

Jane Huston, Curriculum Coordinator
Multistate Academic and Vocational Curriculum Consortium, Inc.

Project developed by

The Multistate Academic and Vocational Curriculum Consortium, Inc.

Board of Directors

Jean McEntire, Arkansas, Chair
Sue Ethelbah, Alaska, Vice-Chair
Jim Fliehler, Iowa, Parliamentarian
Ben Clay, Kansas
Mervin Birdwell, Louisiana
Harley Schlichting, Missouri
Chuck Hopkins, Oklahoma
Larry Nelson, South Dakota
Emmett Eary, Texas

Clark R. Harris, Executive Director

©1997 by the Multistate Academic and Vocational Curriculum Consortium, Inc.

All rights reserved. No part of this book may be reproduced in any form or by any means without written permission from the publisher.

Printed in the United States of America by the
Oklahoma State Department of Vocational and Technical Education
Stillwater, OK 74074-4364

Multistate Academic and Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, OK 74074-4364

The Multistate Academic and Vocational Curriculum Consortium (MAVCC) does not discriminate on the basis of race, creed, color, national origin, sex, age, religion, veteran status, or qualified handicap.

General Electronics Technician: Digital Electronics and Introduction to Microprocessors

Teacher Edition

Table of Contents

Foreword v
Acknowledgments vii
Use of introductory materials ix
Use of this publication xi
Competency profile xv
Instructional/task analysis xvii
Academic and workplace skill classifications and definitions xxi
Related academic and workplace skills list xxiii
Correlation of Electronic Industries Foundation skills list xli

Unit 1: Logic Devices and Circuits

Suggested Activities 1
Answers to Assignment Sheets 9
Answers to Written Test 13
Written Test 17
Unit Evaluation Form 33
Teacher Supplements
  1— Boolean Algebra 37
Transparency Masters
  1— Binary to Decimal Conversions 49
  2— NOT Gate (Inverter) 51
  3— AND Gate 53
  4— NAND Gate 55
  5— OR Gate 57
  6— NOR Gate 59
  7— Exclusive OR Gate 61
  8— NOT Exclusive OR Gate 63
  9— Multivibrators 65
  10— R-S Flip-Flop 67
  11— J-K Flip-Flop 69
  12— Binary Counter 71
  13— Decade Counter 73
  14— Basic Multiplexers 75
  15 – Demultiplexers 77
  16— A/D Converter 79
  17— D/A Converter 81
  18— Basic Encoders 83
  19— Basic Decoders 85

Table of Contents (cont.)

20— BCD to Decimal Decoder 87
21— BCD to Seven-Segment Decoder 89
22— Digital Displays 91

Unit 2: Introduction to Microprocessors

Suggested Activities 1
Answers to Written Test 9
Written Test 13
Unit Evaluation Form 25

Teacher Supplements

1—Report on PC Technology 27

Transparency Masters

1— Microcomputer Interface Blocks 31
2— Simplified Microprocessor Block Diagram 33
3— Microprocessor Block Diagram 35
4— System Architecture 37

Foreword

General Electronics Technician: Digital Electronics and Introduction to Microprocessors is the third in a three-book series that has been developed to replace *Basic Electronics* and *General Electronics Technician*, MAVCC's popular core publications for electronics technology. This volume contains two units that address logic circuits and microprocessors, and the test and repair procedures associated with these devices and circuits. The other two books in the series are *General Electronics Technician: Basic Electronics* and *General Electronics Technician: Semiconductor Devices and Circuits*.

These new instructional materials acknowledge the expanding role of the electronics technician in this world of emerging technologies. They reflect technical developments in hardware and processes, as well as system changes within the industry, such as the increased role of microwave and fiber optic communications. They ensure that training needs as defined by industry are met by addressing the Electronic Industries Foundation proficiencies. Further, they incorporate improvements that MAVCC has made in our curriculum format to make the materials even more user-friendly and flexible while retaining the basic competency-based training concepts that have always been the foundation of MAVCC's instructional materials.

The success of this publication is largely due to the capabilities of the personnel who took part in its development. Appreciation is extended to them for their valuable contributions.

The *General Electronics Technician* series is designed for student use and to assist teachers in organizing and improving instruction. These instructional materials are based on the curriculum-alignment concept of first stating the objectives (objective sheet), developing instructional strategies for teaching to those objectives (information, assignment, and job sheets), and assessing to those same objectives (written test—a criterion-referenced evaluation instrument).

Every effort has been made to make these materials basic, readable, and usable. However, as with all instructional materials, teachers must localize and personalize these materials to meet their community, classroom/laboratory, and individual student's situation. Teachers are encouraged to supplement the materials and to develop strategies for motivating students.

Special attention should be given to the matrix identifying basic academic skills being reinforced in these instructional materials as well as the suggestions on ways to increase reinforcement of academic and workplace skills. By reinforcing these skills, the instructor should assist students in improving their employability skills.

As you use these instructional materials, we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please call or write us.

Jean McEntire, Chair
Board of Directors
Multistate Academic and
Vocational Curriculum Consortium

Clark R. Harris
Executive Director
Multistate Academic and
Vocational Curriculum Consortium

Acknowledgments

All major development projects such as the *General Electronics Technician* series are the product of the contributions of many individuals. This is particularly true in this case because these new instructional materials build on the foundation of two other MAVCC products: *Basic Electronics* and *General Electronic Technician*. Thus, a large part of the credit for these new products is due to the people who originally worked on the predecessor materials.

Basic Electronics was written by Lonnie Hartman and coordinated by Jane Huston. The planning and review committee consisted of:

Ralph Albin	Kirksville, Missouri
Ron Archuleta	Aurora, Colorado
Bob Bixler	Austin, Texas
Don Grob	Salina, Kansas
Horace Hamby	Natchitoches, Louisiana
Lonnie Hartman	Stillwater, Oklahoma
Joe Johnson	Harrison, Arkansas
Mike Julsen	Mason City, Iowa
Marshall Pudwill	Bismark, North Dakota
Leander Stachura	Lincoln, Nebraska
Richard Stedman	Mitchell, South Dakota

General Electronics Technician was written by Ron Vorderstrasse and coordinated by Jane Huston under the guidance of the same committee that planned and reviewed *Basic Electronics*.

Committee members responsible for overseeing the development of this new series include:

Scott Brillhart	Tulsa, Oklahoma
Jim Bullington	Stillwater, Oklahoma
Stan Creitz	Beloit, Kansas
Bill Dews	Shreveport, Louisiana
Lonny Gibbs	Tulsa, Oklahoma
Victor Greenwood	Springdale, Arkansas
Chuck Robertson	Sioux Falls, South Dakota
Frank Secor	Bellaire, Texas
John Smith	Anchorage, Alaska
George Stevenson	Oregon City, Oregon

The new *General Electronics Technician* series was developed under contract with Robert Hilley, who served as the project's technical writer. John Brun did the copy and technical editing and provided invaluable technical support. Kim Patterson was responsible for typesetting and page layout. Nancy Hilley was the graphics coordinator and primary technical illustrator. The series also contains graphics from other sources as acknowledged in copyright permission lines with the individual illustrations, as well as artwork from the original MAVCC publications that was generated by the Oklahoma Department of Vocational and Technical Education Graphics Division. The books were published by the Oklahoma Department of Vocational and Technical Education Print Shop, under the management of Danny Darrow.

Use of Introductory Materials

Introductory materials are included in the teacher edition only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information—such as the table of contents, foreword, and acknowledgments page—information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/learning process.
2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This profile becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.
3. **Instructional/task analysis**—Provides a quick review of the contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.
4. **Academic and workplace skill classifications and definitions**—Defines the basic-skill classifications used by MAVCC. Skill areas reflected by skill groups, subskills, and descriptions have been identified using *What Work Requires of Schools: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.
5. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to the related academic and workplace skills being reinforced.
6. **Correlation to Electronics Industries Foundation skills list**—Shows how the competencies included in this publication satisfy the recommended training objectives developed by the Electronics Industries Foundation.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

General Electronics Technician: Digital Electronics and Introduction to Microprocessors contains two units of instruction:

- Unit 1—Logic Devices and Circuits
- Unit 2—Introduction to Microprocessors

Each instructional unit in a student edition includes some or all of the following components: objective sheet, information sheet, assignment sheets, and job sheets.

This teacher edition includes some or all of the following components for each of the five units of instruction: suggested activities, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, and transparency masters.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.

- Skills that must be demonstrated.

- Amount of class time needed for teacher demonstrations.

- Amount of class time needed for student practice.

- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.

- Resource persons who must be contacted.

Student-edition components

It is a challenge to keep students motivated. Instructors should supplement the student-edition components by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each component can best be taught. Allow students to become involved in preparing and planning their teaching/learning experiences.

Objective sheet. Each unit of instruction is based on performance objectives that state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives, which state the expected performance of each student after completion of the unit of instruction, and specific objectives, which state what the student must do to reach the unit objective.

The objectives should be stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information-sheet, assignment-sheet, job-sheet, and written-test items.

Information sheet. The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Assignment sheets. Assignment sheets provide students with pencil-and-paper activities that give students the opportunity to make practical application of the knowledge in the information sheet. Criteria are provided to objectively evaluate student performance.

Job sheets. Job sheets are an important segment of each unit; they give the instructor direction as to the psychomotor skills to be taught and allow both the student and instructor to check student progress toward the accomplishment of those skills. Each job sheet provides criteria to allow the instructor to objectively evaluate student performance of a particular psychomotor skill. The instructor should discuss the equipment and materials to be used—emphasizing the specific equipment and materials available in the classroom and/or laboratory—and demonstrate the job-sheet procedure before having students practice the psychomotor skill.

Teacher-edition components

Suggested activities. The suggested activities assist teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teaching suggestions, and skill areas have been noted in bold. The teacher should read the suggested activities before teaching a unit and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the instructor to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Use of This Publication

The supplemental resources contain suggestions for media that the instructor may choose to use in support of the delivery portion of the teaching/learning process. Generally, none of the titles listed were more than approximately ten years old at the time of publication. This is done to provide the most current information in a contemporary style, as many students—especially adolescent students—may be distracted from the content of media by the presentation format, appearance of persons and equipment in the program, wear-and-tear of the physical medium, and other factors unrelated to the content information. However, many good films, videotapes, and similar media exist that were produced more than a decade ago, particularly those related to basic concepts such as Ohm's Law, electrical flow, fundamentals of semiconductor manufacture and common devices, etc. Instructors should assess the effectiveness of such programs within their specific course with their student population when selecting media to use.

Assignment-sheet and written-test answers. Assignment-sheet and written-test answers are designed to assist the teacher in evaluating student performances on the assignment sheets and written test.

Written test. This component is a criterion-referenced evaluation of every cognitive objective listed in the information sheet. If the instructor has added, deleted, or modified objectives, appropriate changes should be made on the written test. It is recommended that the test be divided into shorter tests covering three or four objectives at a time and given soon after those objectives are covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired. The test is included in the teacher edition only, but duplication is permitted for student use.

Teacher supplements. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher-level materials to stretch the advanced student, with remedial information or practice for the less-advanced student, and with state-of-the art information in which the instructor may not have background or with information that is not readily available in other sources. Some teacher supplements may be duplicated for student use and are marked accordingly.

Transparency masters. Transparency masters are used to direct the students' attention to the topic of discussion. Transparency masters may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

General Electronics Technician:
Digital Electronics and Introduction to Microprocessors

Competency Profile

Name: ______________________________________

Directions: Evaluate the student using one of the optional rating scales below. Write the appropriate numbers/letters to indicate the degree of competency achieved. The descriptions associated with each of the numbers/letters focus on a level of student performance for each of the tasks listed. The written-test score line is provided for optional teacher use. It may not be applicable in all cases.

Optional rating scales

Option A

Rating scale 4 — **Skilled** - Can perform job with no additional training.
3 — **Moderately skilled** - Has performed job during training program; limited additional training may be required.
2 — **Limited skill** - Has performe during training program; additional training is required to develop skill.
1 — **Unskilled** - Is familiar with proc t is unable to perform job.
0 — **No exposure** - No information tice provided during training program; complete training is required.
NA — **Non-applicable.**

Option B

Yes — Can perform with no additional training
No — Is unable to perform satisfactorily

Unit 1: Logic Devices and Circuits

______ 1. Convert octal numbers to decimal numbers.
______ 2. Convert decimal numbers to octal numbers.
______ 3. Convert decimal numbers to binary numbers.
______ 4. Convert binary numbers to base ten numbers.
______ 5. Use the double-dabble method to convert binary numbers to decimal numbers.
______ 6. Convert binary numbers to octal numbers.
______ 7. Convert octal numbers to binary numbers.
______ 8. Convert binary numbers to hexadecimal numbers.
______ 9. Convert hexadecimal numbers to binary numbers.
______ 10. Complete logic tables.
______ 11. Apply Boolean operations to minimizing logic circuits.
______ 12. Construct and test an "AND" gate circuit.
______ 13. Construct and test an "OR" gate circuit.
______ 14. Construct and test a "NAND" gate circuit.
______ 15. Construct and test a "NOR" gate circuit.

Competency Profile

_______ 16. Construct and test an "exclusive-OR" gate circuit.
_______ 17. Construct and test a four-bit shift register.
_______ 18. Construct and test a flip-flop circuit.
_______ 19. Construct and test a J-K counter circuit.
_______ 20. Construct and test an A/D converter.
_______ 21. Construct and test a D/A converter.
_______ 22. Construct and test a BCD to seven-segment decoder.
_______ 23. Troubleshoot logic circuits.
_______ 24. ____

_______ Written-test score

Unit 2: Introduction to Microprocessors

_______ 1. Write and run a machine language driver program to check read/write memory location.
_______ 2. Use a digital voltmeter to test supply voltages on a microcomputer system bus.
_______ 3. Use an oscilloscope to check a computer clock system.
_______ 4. Set up and configure a personal computer.
_______ 5. Troubleshoot microprocessor circuits.
_______ 6. ____

_______ Written-test score

Comments: ____

____

Evaluator: ______________________________ **Date:** ______________

Permission to duplicate this profile is granted.

General Electronics Technician: Digital Electronics and Introduction to Microprocessors

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 1: Logic Devices and Circuits	
1. Definitions of terms associated with logic devices and circuits	
2. How signals represent information	
3. Numbering systems used with logic circuits	
4. Types of logic gates	
5. Logic gate symbols	
6. Characteristics of multivibrator circuits	
7. Diagram of a set-reset flip-flop	
8. Diagram of a J-K flip-flop	
9. Types of counters	
10. Diagram of a shift register	
11. Functions that can be performed by shift registers	
12. Statements regarding the operation of timing circuits	
13. Functions of clock and timing circuits	
14. Functions of arithmetic-logic circuits	
15. Statements about the operation of multiplexer circuits	
16. Types of analog/digital conversion circuits	

Instructional/Task Analysis

Unit 1: Logic Devices and Circuits (cont.)

Related Information: What the student should know	Application: What the student should be able to do
17. Operation of encoder/decoder circuits	22. Convert octal numbers to decimal numbers
18. Statements regarding noise problems	23. Convert decimal numbers to octal numbers
19. Common IC logic families	24. Convert decimal numbers to binary numbers
20. Characteristics of electronic displays	25. Convert binary numbers to base ten numbers
21. Types of displays	26. Use the double-dabble method to convert binary numbers to decimal numbers
	27. Convert binary numbers to octal numbers
	28. Convert octal numbers to binary numbers
	29. Convert binary numbers to hexadecimal numbers
	30. Convert hexadecimal numbers to binary numbers
	31. Complete logic tables
	32. Apply Boolean operations to minimizing logic circuits
	33. Construct and test an "AND" gate circuit
	34. Construct and test an "OR" gate circuit
	35. Construct and test a "NAND" gate circuit
	36. Construct and test a "NOR" gate circuit
	37. Construct and test an "exclusive-OR" gate circuit

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 1: Logic Devices and Circuits (cont.)	
	38. Construct and test a four-bit shift register
	39. Construct and test a flip-flop circuit
	40. Construct and test a J-K counter circuit
	41. Construct and test an A/D converter
	42. Construct and test a D/A converter
	43. Construct and test a BCD to seven-segment decoder
	44. Troubleshoot logic circuits
Unit 2: Introduction to Microprocessors	
1. Definitions of terms associated with microprocessors	
2. Parts of a computer block diagram	
3. Sections of a computer	
4. Purpose of the two major sections of the central processing unit	
5. Functional areas of the CPU register section	
6. Three ways in which information flows through a microprocessor	
7. Statements about the flow of information through a microprocessor	
8. Types of memory devices	
9. Types of bus construction	
10. Statements about the system bus	
11. Statements about data busses	

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 2: Introduction to Microprocessors (cont.)	
12. Statements about address busses 13. Statements about control busses 14. Statements about clock timing in a microprocessor 15. Purpose and operation of an interrupt 16. Statements about computer operation 17. Use and functioning of machine and assembler languages 18. Characteristics of various communications standards 19. Two major purposes of a computer operating system 20. Types of computer peripherals	21. Write and run a machine language driver program to check read/write memory location 22. Use a digital voltmeter to test supply voltages on a microcomputer system bus 23. Use an oscilloscope to check a computer clock system 24. Set up and configure a personal computer 25. Troubleshoot microprocessor circuits

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
	Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Listening	Receiving, interpreting, and responding to verbal messages and other cues.
	Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
Thinking skills	Creative thinking	Using imagination to generate new ideas.
	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills.
	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Career awareness, development, and mobility	Assessing self accurately, setting personal goals, establishing and implementing a plan, and monitoring progress.
	Integrity/honesty	Choosing an ethical course of action when faced with making a decision that may break with personal and societal values and recognizing the impact of violating these beliefs and codes on an organization, self, and others.
	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal.
	Coaching	Helping others learn new skills.
	Leadership	Communicating ideas to justify position; accepting responsibility for others; and encouraging, persuading, convincing, or otherwise motivating an individual or group.
	Negotiation	Resolving conflict between two or more individuals through discussion and compromise.
	Customer service	Working and communicating with customers to satisfy their expectations.
	Cultural diversity	Working well with men and women and with a variety of ethnic, social, or educational backgrounds.
Resources	Time	Selecting relevant, goal-oriented activities, ranking them in order of importance, allocating time, and understanding, preparing, and following schedules.
	Money	Using or preparing budgets, making forecasts, keeping records, and making adjustments to meet objectives.
	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Human resources	Assessing skills and distributing work accordingly; evaluating performance and providing feedback.
Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way.
	Interpretation	Selecting and analyzing information and communicating the results to others.
	Processing	Using computers to acquire, organize, analyze, and communicate information.
Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
	Monitoring	Distinguishing trends, predicting impact of actions on system operations, diagnosing deviations in systems' performance, and correcting malfunctions.
	Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems.
Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
	Application	Demonstrating proper procedures for setting up and operating equipment.
	Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

General Electronics Technician:
Digital Electronics and Introduction to Microprocessors

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Logic Devices and Circuits			
Convert octal numbers to decimal numbers (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Convert decimal numbers to octal numbers (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Convert decimal numbers to binary numbers (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Logic Devices and Circuits (cont.)			
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Convert binary numbers to base ten numbers (A.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Use the double-dabble method to convert binary numbers to decimal numbers (A.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Logic Devices and Circuits (cont.)			
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Convert binary numbers to octal numbers (A.S. 6)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Convert octal numbers to binary numbers (A.S. 7)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Logic Devices and Circuits (cont.)			
Convert binary numbers to hexadecimal numbers (A.S. 8)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Convert hexadecimal numbers to binary numbers (A.S. 9)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Complete logic tables (A.S. 10)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Logic Devices and Circuits (cont.)			
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Apply Boolean operations to minimizing logic circuits (A.S. 11)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Construct and test an "AND" gate circuit (J.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.

Related Academic and Workplace Skills List

Unit 1: Logic Devices and Circuits (cont.)

Task	Skill group	Subskill	Description
Construct and test an "OR" gate circuit (J.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a "NAND" gate circuit (J.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Logic Devices and Circuits (cont.)			
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a "NOR" gate circuit (J.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Listening	Receiving, interpreting, and responding to verbal messages and other cues.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Logic Devices and Circuits (cont.)			
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test an "exclusive-OR" gate circuit (J.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a four-bit shift register (J.S. 6)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Logic Devices and Circuits (cont.)			
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a flip-flop circuit (J.S. 7)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.

Related Academic and Workplace Skills List

Unit 1: Logic Devices and Circuits (cont.)

Task	Skill group	Subskill	Description
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a J-K counter circuit (J.S. 8)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test an A/D converter (J.S. 9)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
		Unit 1: Logic Devices and Circuits (cont.)	
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a D/A converter (J.S. 10)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
		Unit 1: Logic Devices and Circuits (cont.)	
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a BCD to seven-segment decoder (J.S. 11)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.

Related Academic and Workplace Skills List

Unit 1: Logic Devices and Circuits (cont.)

Task	Skill group	Subskill	Description
Troubleshoot logic circuits (J.S. 12)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

Unit 2: Introduction to Microprocessors

Write and run a machine language driver program to check read/write memory location (J.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.

Related Academic and Workplace Skills List

Unit 2: Introduction to Microprocessors (cont.)

Task	Skill group	Subskill	Description
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Use a digital voltmeter to test supply voltages on a microcomputer system bus (J.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
		Unit 2: Introduction to Microprocessors (cont.)	
		Application	Demonstrating proper procedures for setting up and operating equipment.
Use an oscilloscope to check a computer clock system (J.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Set up and configure a personal computer (J.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Listening	Receiving, interpreting, and responding to verbal messages and other cues.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 2: Introduction to Microprocessors (cont.)			
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Troubleshoot microprocessor circuits (J.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.

Task	Skill group	Subskill	Description
Unit 2: Introduction to Microprocessors (cont.)			
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

Correlation to Electronics Industries Foundation Skills List

Note: The Electronic Industries Foundation and its parent organization, the Electronic Industries Association, have coordinated the development of a skills list for the entry-level electronics technicians. The skills are defined in *Measurement Criteria for Entry-Level Electronics Technician Skills,* a supplement to the skills standard publication *Raising the Standard—Electronics Technician Skills for Today and Tomorrow.* Skills are defined in five areas: additional skills (communications, electromechanics, LASER applications), desirable behavior and work habits, basic and practical skills (reading, math, physics, technical literacy, etc.), test equipment and tools skills, and technical skills. In recognition of the relevance of this extensive task analysis, MAVCC has attempted to address all of the EIA/EIF technical skills in the development of the *General Electronics Technician Series.* The following table lists the EIA/EIF technical skills as of the time of publication and shows at least one example of how that skill is addressed in these instructional materials. This correlation represents the opinions of the development team in interpreting the EIA/EIF skills and is not intended to imply agreement or endorsement by the Electronic Industries Foundation. Instructors and administrators wanting more information about the EIA/EIF skills list may contact the foundation directly at the following address:

919 18th Street, NW, Suite 900
Washington, DC 20006

Note: This table lists objectives for all three books in the *General Electronics Technician* series and may not reflect the latest revisions to the other two volumes. Users should check the current edition of each work to get the most accurate listing.

Skill Code	**Skill Description**	**Applicable Publication**	**Unit Number**	**Objective(s)**
A.01	Demonstrate an understanding of proper safety techniques for all types of circuits and components	Basic	2	22-35
A.02	Demonstrate an understanding of and comply with relevant OSHA safety standards	Basic	2	27-42
A.03	Demonstrate an understanding of proper troubleshooting techniques	Basic	3	21, 23
A.04	Demonstrate an understanding of basic assembly skills using hand and power tools	Basic	3	24-38
A.05	Demonstrate an understanding of acceptable soldering/desoldering techniques, including through-hole and surface mount devices	Basic	3	31, 33, 37-42
A.06	Demonstrate an understanding of proper solderless connections	Basic	3	6, 7, 26-29, 32
A.07	Demonstrate an understanding of the use of data books and cross reference/technical manuals to specify and requisition electronic components	Basic	3	22
		Semiconductors	1	49
			2	53
A.08	Demonstrate an understanding of the interpretation and creation of electronic schematics, technical drawings and flow diagrams	Basic	1	16, 30, 37, 53

Correlation to Electronics Industries Foundation Skills List

A.09	Demonstrate an understanding of design curves, table, graphs, and recording of data	Semiconductors	1	52, 58, 66
A.10	Demonstrate an understanding of color codes and other component descriptors	Basic Semiconductors	4 2	18, 19, 32 4-7
A.11	Demonstrate an understanding of site electrical and environmental survey	Basic	2	Supplements 12 and 13
A.12	Demonstrate the use of listening skills or assistive devices to assess signs and symptoms of malfunctions	Basic	3	21
B.01	Demonstrate an understanding of sources of electricity in DC circuits	Basic	1	6
B.02	Demonstrate an understanding of principles and operation of batteries	Basic	4	5
B.03	Demonstrate an understanding of the meaning of and relationships among and between voltage, current resistance and power in DC	Basic	1 4	7, 8 33-47, 49-54
B.04	Demonstrate an understanding of the measurement of resistance of conductors and insulators and the computation of conductance	Basic	1 3	5, 46 5
B.05	Demonstrate an understanding of application of Ohm's Law to series, parallel and series-parallel circuits	Basic	1	9
B.06	Demonstrate an understanding of magnetic properties of circuits and devices	Basic	1	38-44
B.07	Demonstrate an understanding of the physical, electrical, characteristics of capacitors and inductors	Basic	5	18-45
B.08	Understand principles and operations of DC series circuits	Basic	1 4	18, 19 33-37
B.09	Fabricate and demonstrate DC series circuits	Basic	2 4	47 47, 28
B.10	Troubleshoot and repair DC series circuits	Basic	4	65
B.11	Understand principles and operations of DC parallel circuits	Basic	1 4	20, 21 38-40
B.12	Fabricate and demonstrate the DC parallel circuits	Basic	2	47
B.13	Troubleshoot and repair parallel circuits	Basic	4	66
B.14	Understand the principles and operations of DC series-parallel and bridge circuits	Basic	1 4	22, 23 30, 31, 41-45
B.15	Fabricate and demonstrate DC series-parallel and bridge circuits	Basic	4	51-53
B.16	Troubleshoot and repair series-parallel and bridge circuits	Basic	4	66
B.17	Understand the principles and operations of Wheatstone Bridge	Basic	4	30, 31, 53
B.18	Understand the principles and operations of DC voltage divider circuits (loaded and unloaded)	Basic	4	28, 29
B.19	Fabricate and demonstrate the DC voltage divider circuits (loaded and unloaded)	Basic	4	50
B.20	Troubleshoot and repair DC voltage divider circuits (loaded and unloaded)	Basic	4	66

Correlation to Electronics Industries Foundation Skills List

B 21	Understand principles and operations of DC RC and RL circuits	Basic	4	18-26, 33-41, 59-71
B 22	Fabricate and demonstrate DC RC and RL circuits	Basic	5	81, 84
B 23	Troubleshoot and repair DC RC and RL circuits	Basic	5	66
B 24	Demonstrate an understanding of measurement of power in DC circuits	Basic	4	37, 40, 45
C 01	Demonstrate an understanding of sources of electricity in AC circuits	Basic	1 5	6 8-12
C 02	Demonstrate an understanding of the properties of an AC signal	Basic	5	4-6
C 03	Demonstrate an understanding of the principles of operation and characteristics of sinusoidal and non-sinusoidal wave forms	Basic	5	5
C 04	Demonstrate an understanding of basic motor/generator theory and operation	Basic	5	12, 13
C 05	Demonstrate an understanding of measurement of power in AC circuits	Basic	5	56, 74
C 06	Demonstrate an understanding of the principle and operation of various power conditioning: (isolation transformers, surge suppressors, uninterruptable power systems)	Basic	5	47, 48
C 07	Demonstrate an understanding of the principle and operation of safety grounding systems: (lightning arresters, ground fault interrupters, etc.)	Basic	1	14-16
C 08	Understand principles and operations of AC capacitive circuits	Basic	5	27-41, 64-68
C 09	Fabricate and demonstrate AC capacitive circuits	Basic	5	84, 87
C 10	Troubleshoot and repair AC capacitive circuits	Basic	5	90
C 11	Understand principles and operations of AC inductive circuits	Basic	5	18-26, 59-63
C 12	Fabricate and demonstrate AC inductive circuits	Basic	5	80, 81
C 13	Troubleshoot and repair AC inductive circuits	Basic	5	90
C 14	Understand principles and operations of AC circuits using transformers	Basic	5	14-17, 74, 75
C 15	Demonstrate an understanding of impedance matching theory	Basic	5	53
C 16	Fabricate and demonstrate AC circuits using transformers	Basic	5	78, 79
C 17	Troubleshoot and repair AC circuits using transformers	Basic	5	90
C 18	Understand principles and operations of AC differentiator and integrator circuits (determine RC and RL time constants)	Basic	5	49, 66
C 19	Fabricate and demonstrate the operation of differentiators and integrators			

Correlation to Electronics Industries Foundation Skills List

C 20	Troubleshoot and repair AC differentiator and integrator circuits	Basic	5	90
C 21	Understand principles and operations of AC series and parallel resonant circuits	Basic	5	43, 45, 62, 73
C 22	Fabricate and demonstrate AC series and parallel resonant circuits	Basic	5	88, 89
C 23	Troubleshoot and repair AC series and parallel resonant circuits	Basic	5	90
C 24	Understand principles and operations of AC RC, RL, and RLC circuits	Basic	5	24-45, 59-73
C 25	Fabricate and demonstrate AC RC, RL and RLC circuits	Basic	5	81, 87-89
C 26	Troubleshoot and repair AC RC, RL and RLC circuits	Basic	5	90
C 27	Understand principles and operations of AC frequency selective filter circuits	Basic	5	50-52
C 28	Fabricate and demonstrate the operation of frequency selective filter circuits	Semiconductors	2	59
C 29	Troubleshoot and repair AC frequency selective filter circuits	Basic	5	90
C 30	Understand principles and operations of AC polyphase circuits	Basic	5	16, 74, 75
C 31	Understand principles and operations of AC phase locked loop circuits	Semiconductors	2	32
C 32	Troubleshoot and repair AC phase locked loop circuits	Semiconductors	2	61
D 01	Demonstrate an understanding of the properties of semiconductor materials	Semiconductors	1	4-6
D 02	Demonstrate an understanding of PN junctions	Semiconductors	1	6
D 03	Demonstrate an understanding of bipolar transistors	Semiconductors	1	15-23
D 04	Demonstrate an understanding of Field Effect Transistors	Semiconductors	1	24-31
D 05	Demonstrate an understanding of special diodes and transistors	Semiconductors	1	7-31, 41
D 06	Understand principles and operations of diode circuits	Semiconductors	1	9
D 07	Fabricate and demonstrate diode circuits	Semiconductors	1	58-61
D 08	Troubleshoot and repair diode circuits	Semiconductors	1	73
D 09	Understand principles and operations of optoelectronic circuits (gate isolators, interrupt sensors, infra-red sensors, etc.)	Semiconductors	2	49
D 10	Fabricate and demonstrate optoelectronic circuits	Semiconductors	1	61
D 11	Troubleshoot and repair optoelectronic circuits	Semiconductors	2	61
D 12	Understand principles and operations of single stage amplifiers	Semiconductors	1	34
D 13	Fabricate and demonstrate the operation of the single stage amplifiers	Semiconductors	1	67

Correlation to Electronics Industries Foundation Skills List

D 14	Troubleshoot and repair single-stage amplifiers	Semiconductors	1	73
D 15	Understand principles and operations of thyristor circuitry	Semiconductors	1	44, 45
D 16	Fabricate and demonstrate thyristor circuitry	Semiconductors	1	60, 72
D 17	Troubleshoot and repair thyristor circuitry	Semiconductors	1	73
E 01	Understand principles and operations of multistage amplifiers	Semiconductors	1	32-40, 55
E 02	Fabricate and demonstrate the operation of multistage amplifiers	Semiconductors	1	68, 69
E 03	Troubleshoot and repair multistage amplifiers	Semiconductors	1	73
E 04	Understand principles and operations of IF circuits	Semiconductors	2	41
E 05	Fabricate and demonstrate IF circuits	See MAVCC's *Electronics Communications*		
E 06	Troubleshoot and repair IF circuits	Semiconductors	2	61
E 07	Understand principles and operations of linear power supplies and filters	Semiconductors	3	2-14
E 08	Fabricate and demonstrate linear power supplies and filters	Semiconductors	3	21-24
E 09	Troubleshoot and repair linear power supplies and filters	Semiconductors	3	17, 25
E 10	Understand principles and operations of operational amplifier circuits	Semiconductors	2	16-23
E-11	Fabricate and demonstrate operational amplifier circuits	Semiconductors	2	54-60
E 12	Troubleshoot and repair operational amplifier circuits	Semiconductors	2	61
E 13	Understand principles and operations of audio power amplifiers	Semiconductors	1	35, 36, 39
E 14	Fabricate and demonstrate audio power amplifiers	Semiconductors	1	67-70
E 15	Troubleshoot and repair audio power amplifiers	Semiconductors	1	73
E 16	Understand principles and operations of regulated and switching power supply circuits	Semiconductors	3	2-16
E 17	Troubleshoot and repair regulated and switching power supply circuits	Semiconductors	3	25
E 18	Understand principles and operations of active filter circuits	Semiconductors	2	33, 34
E 19	Troubleshoot and repair active filter circuits	Semiconductors	2	61
E 20	Understand principles and operations of sinusoidal and non-sinusoidal oscillator circuits	Semiconductors	2	27-31, 58
E 21	Troubleshoot and repair sinusoidal and non-sinusoidal oscillator circuits	Semiconductors	2	61
E 22	Understand principles and operations of fiber optic circuits using photodiodes or LASERS	Semiconductors	2	45, 46

Correlation to Electronics Industries Foundation Skills List

E 23	Troubleshoot and repair fiber optic circuits using photodiodes or LASERS	Semiconductors	2	61
E 24	Understand principles and operations of RF circuits	Semiconductors	2	39, 40
E 25	Fabricate and demonstrate RF circuits	See MAVCC's *Electronics Communications*		
E 26	Troubleshoot and repair RF circuits	Semiconductors	2	61
E 27	Understand principles and operations of signal modulation systems (AM, FM, Stereo)	Semiconductors	2	42
E 28	Troubleshoot and repair signal modulation systems (AM, FM, Stereo)	Semiconductors	2	61
E 29	Demonstrate an understanding of motor phase shift control circuits	Semiconductors	2	32, 36, 47, 48
E 30	Understand principles and operations of microwave circuits	Semiconductors	2	43, 44
F 01	Demonstrate an understanding of the characteristics of integrated circuit (IC) logic families	Digital	1	2
F 02	Demonstrate an understanding of minimizing logic circuits using Boolean operations	Digital	1	33
F 03	Understand principles and operations of linear integrated circuits	Semiconductors	2	2-50
F 04	Troubleshoot and repair linear integrated circuits	Semiconductors	2	61
F 05	Understand principles and operations of types of logic gates	Digital	1	3, 4
F 06	Fabricate and demonstrate types of logic gates	Digital	1	34-38
F 07	Troubleshoot and repair types of logic gate circuits	Digital	1	46
F 08	Understand principles and operations of combinational logic circuits	Digital	1	20
F 09	Fabricate and demonstrate combinational logic circuits	Digital	1	39-45
F 10	Troubleshoot and repair combinational logic circuits	Digital	1	46
F 11	Understand principles and operations of types of flip-flop circuits	Digital	1	6, 7
F 12	Fabricate and demonstrate the operation of flip-flop circuits	Digital	1	40
F 13	Troubleshoot and repair flip-flop circuits	Digital	1	46
F 14	Understand principles and operations of types of registers and counters	Digital	1	8-11
F 15	Fabricate and demonstrate types of registers and counters	Digital	1	39, 41
F 16	Troubleshoot and repair types of registers and counters	Digital	1	46
F 17	Understand principles and operations of clock and timing circuits	Digital	1	12, 13
F 18	Fabricate and demonstrate clock and timing circuits	Digital	1	45

Correlation to Electronics Industries Foundation Skills List

F 19	Troubleshoot and repair clock and timing circuits	Digital	1	46
F 20	Understand principles and operations of types of arithmetic-logic circuits	Digital	1	14
F 21	Troubleshoot and repair types of arithmetic-logic circuits	Digital	1	46
F 22	Understand principles and operations of types of multiplexer and de-multiplexer circuits	Digital	1	15, 16
F 23	Troubleshoot and repair multiplexer and de-multiplexer circuits	Digital	1	46
F 24	Understand principles and operations of types of digital to analog and analog to digital circuits	Digital	1	43, 44
F 25	Troubleshoot and repair types of digital-to-analog and analog-to-digital circuits	Digital	1	46
F 26	Understand principles and operations of types of digital display circuits	Digital	1	2, 44
F 27	Troubleshoot and repair types of digital display circuits	Digital	1	46
F 28	Understand principles and operations of power distribution and noise problems	Digital	1	19
F 29	Troubleshoot and repair power distribution and noise problems	Digital	1	46
F 30	Understand principles and operations of types of digital encoders and decoders	Digital	1	18
F 31	Troubleshoot and repair types of digital encoders and decoders	Digital	1	46
F 32	Understand principles and operations of digital display devices	Digital	1	20, 21
F 33	Troubleshoot and repair digital display devices	Digital	1	46
G 01	Demonstrate an understanding of microprocessor interfaces	Digital	2	3
G 02	Troubleshoot and repair microprocessor interfaces	Digital	2	26
G 03	Demonstrate an understanding of essential microprocessor components	Digital	2	3
G 04	Demonstrate an understanding of microprocessor BUS concepts	Digital	2	9-12
G 05	Demonstrate an understanding of microprocessor components and terminology	Digital	2	1, 2
G 06	Understand principles and operation of types of microprocessor memory circuits	Digital	2	8
G 07	Troubleshoot and repair types of microprocessor memory circuits	Digital	2	26
G 08	Understand principles and operations of microprocessor machine code and instruction sets	Digital	2	16-18
H 01	Demonstrate an understanding of microcomputer operating systems	Digital	2	20
H 02	Demonstrate an understanding of essential microcomputer components	Digital	2	15

Correlation to Electronics Industries Foundation Skills List

H.03	Demonstrate an understanding of microcomputer peripherals	Digital	2	21
H.04	Setup and configure a microcomputer using available operating systems and software packages peripherals	Digital	2	25
H.05	Troubleshoot and replace microcomputer peripherals	Digital	2	26

46

Logic Devices and Circuits
Unit 1

Suggested Activities

Instructional Plan

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note the suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain films, videotapes, and other media to supplement instruction of this unit. See ordering information in the suggested resources section.

- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only and should be used with objectives as indicated below.

  TM 1—Binary to Decimal Conversions (Objective 3)
  TM 2—NOT Gate (Inverter) (Objective 5)
  TM 3—AND Gate (Objective 5)
  TM 4—NAND Gate (Objective 5)
  TM 5—OR Gate (Objective 5)
  TM 6—NOR Gate (Objective 5)
  TM 7—Exclusive OR Gate (Objective 5)
  TM 8—NOT exclusive OR Gate (Objective 5)
  TM 9—Multivibrators (Objective 6)
  TM 10—R-S Flip-Flop (Objective 7)
  TM 11—J-K Flip-Flop (Objective 8)
  TM 12—Binary Counter (Objective 9)
  TM 13—Decade Counter (Objective 9)
  TM 14—Basic Multiplexers (Objective 15)
  TM 15—Demultiplexers (Objective 15)
  TM 16—A/D Converter (Objective 16)
  TM 17—D/A Converter (Objective 16)
  TM 18—Basic Encoders (Objective 17)
  TM 19—Basic Decoders (Objective 17)
  TM 20—BCD to Decimal Decoder (Objective 17)
  TM 21—BCD to Seven-Segment Decoder (Objective 17)
  TM 22—Digital Displays (Objective 20)

Suggested Activities

- Select teacher components (supplement, written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution. The supplement included in this unit is designed for use with the objective indicated below.

  Supplement 1—Boolean Algebra (Objective 32)

- Prepare classroom. Put up posters and charts and display articles and other references related to the objectives of this unit. Component manufacturers distribute posters of products, characteristic curves, schematics, and other materials that would be useful in supporting this unit. Particularly applicable to this unit are posters of logic devices and truth tables. Show types of devices covered in this unit, including types of displays.

Delivery and Application

Unit Introduction

- Discuss unit and specific objectives.
- Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets and job sheets. Review with students the criteria for evaluation of each of these activities.

Teaching Suggestions

The skill areas appearing in bold-face type in the teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of School: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.

- Walk the students through the objective on how signals can represent information. Use generous examples and relate them to actual devices, especially those with which the students will be familiar. Emphasize the fact that there are numerous number systems, while saving the details for the later objective. Use Morse code as an example of signals representing information, an analogy that will help later when discussing decoders. Relate the principle of Morse code to signals in electronic devices. **(Listening; science; arithmetic/mathematics; seeing things with the mind's eye; responsibility)**

Suggested Activities

- Determine the best method for presenting number systems based on your students' backgrounds, experience, and skills. Relate the systems to each other to show similarities and differences. Give examples of how the systems are used in electronics. Consider doing the associated assignment sheets in conjunction with presenting the material in the information sheet. Use seven-segment displays to show an actual conversion process. **(Listening; reading; writing; arithmetic/mathematics; seeing things in the mind's eye; interpreting and processing information; system interrelationships)**

- Introduce the basic concept of gates and the difference between AND and NAND gates and then shift more of the interpretation to the students—that is, let them hypothesize the differences in output and symbols for OR and NOR gates. Expand on this by having them speculate as to applications for various types of output signals. Once the students understand the basics of two-input circuits, have them develop truth tables for three- and four-signal circuits. For three-input circuits, you may have them fill in only the outputs and, when they are comfortable with that, have them build four-input tables from scratch. Make sure that they understand how the number of truth table entries grow as the number of inputs grows. **(Listening; reading; writing; reasoning; acquiring, organizing, interpreting, and processing information; science; applying technology; system interrelationships)**

- As you cover the various types of devices, relate them to the logic gates that they contain and the mathematical/electrical functioning of the devices. Discuss applications in equipment. Discuss the packages in which the devices are available, such as two- and four-flip-flop ICs. Demonstrate circuit operations for flip-flops, counters, multiplexers, etc. Discuss device nicknames and other trade names used for the circuits and devices. Discuss and display gate arrays, including field-programmable gate arrays. Discuss their applications, programming, limitations, drawbacks, advantages, etc. **(Listening; reasoning; selecting and applying technology; science; arithmetic/mathematics; seeing things with the mind's eye)**

- Tour a manufacturing plant or invite a manufacturing representative to talk to your class about display technology. The drive for ever-more powerful and portable computers has provided a tremendous motivation to provide lighter, brighter, bigger, higher resolution, more colorful, and flatter displays. This race has received further fuel from video-game companies, automotive manufacturers, test equipment companies, and others who are looking for ways to clearly and attractively present real-time dynamic information. Discuss issues like sunlight readability, pixel defects, color saturation, viewing angle, and similar factors related to the operator's ability to extract useful information from the display and the constraints of heat, weight, manufacturability, cold, etc. Discuss high-density television and flat-panel technology, as well as active and passive matrix designs. **(Listening; reasoning; applying technology; seeing things with the mind's eye; system interrelationships; materials and facilities)**

Evaluation

- Discuss with students the use of the Unit Evaluation Form. Explain the rating scale that will be used for student evaluation.
- Copy written test and give to students as pretest. Record pretest score on the Unit Evaluation Form.
- Evaluate assignment sheets. See the evaluation criteria listed at the top of each assignment sheet and the component "Answers to Assignment Sheets."
- Evaluate job sheets. See the evaluation criteria listed at the top of each job sheet.
- Give and evaluate written test.
- Compile written-test, assignment-sheet, and job-sheet scores on the Unit Evaluation Form. Include any additional assignments.
- Measure competency gains by comparing written pretest scores with posttest scores.
- Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- Reteach and retest as required.

Instructions for Evaluating Student Performance

- When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Suggested Activities

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

1 — Skilled—Can perform job with no additional training.
2 — Moderately skilled—Has performed job during training program; limited additional training may be required.
3 — Limited skill—Has performed job during training program; additional training is required to develop skill.
4 — Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Suggested Resources

Resources Used in Developing This Unit

- *Basic Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Communications Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1988.
- Davidson, Homer L. *Electronic Troubleshooting and Repair Handbook.* New York: McGraw-Hill, 1995.
- Davidson, Homer L. *Troubleshooting and Repairing Compact Disc Players.* 2nd Ed. New York, New York: TAB Books, 1994.
- *General Electronics Technician.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, Inc., 1975.

Suggested Activities

- *Home Electronics.* Alexandria, Virginia: Time-Life Books, 1988.
- McMenamin, J. Michael. *Applied Electronic Devices and Analog ICs.* Albany, New York: Delmar Publishing, Inc., 1995.
- Newby, Bruce. *Electronic Signal Conditioning.* Oxford, England: Butterworth-Heinemann Ltd., 1994.
- Pallás-Areny, Ramón and John G. Webster. *Sensors and Signal Conditioning.* New York: John Wiley & Sons, Inc., 1991.
- Reis, Ronald A. *Electronic Project Design and Fabrication.* 3rd edition. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1995.
- Roehrig, Guido and Ulrich Schueller. *Upgrading and Maintaining Your PC.* Grand Rapids, Michigan: Abacus, 1991.
- Schuler, Charles A. *Electronics Principles and Applications.* 4th edition. New York: Glencoe Division, Macmillan/McGraw-Hill School Publishing Company, 1994.
- Simpson, Colin D. *Principles of Electronics.* Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1996.
- Villanucci, Robert S., Alexander W. Avtgis, and William F. Megow. *Electronics Techniques: Shop Practices and Construction.* 5th Edition. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1996.

Supplemental Resources

Print Media

- Data sheets for applicable semiconductor devices. Available from manufacturers and in handbooks.
- Schematics for circuits discussed in conjunction with this unit. Available from equipment manufacturers.

Non-print Media

- *Basic Digital Math.* Covers digital number systems, with emphasis on binary. Produced in 1990. Available from: Bergwall Productions, Inc.; P.O. Box 238; Garden City, NY 11530-0238; 800-645-3565.
- *Combinational Logic.* Released in 1989, this program is part of a series dealing with digital circuits and devices. Available from: Massachusetts Institute of Technology; Video Courses CEC; 77 Massachusetts Ave.; Cambridge, MA 02139.

Suggested Activities

- *Digital Codes and Numbering Explained.* Covers binary, hexadecimal, and other numbering systems. Available from: Bergwall Productions, Inc.; P.O. Box 238; Garden City, NY 11530-0238; 800-645-3565.
- *How Circuits Make Decisions.* A basic explanation of logic devices and circuit applications. Available from: Texas Instruments Learning Center; Mail Station 54; P.O. Box 225012; Dallas, TX 75265.
- *Introduction to Digital Electronics.* Part of a series of programs produced in 1989 that covers a wide-range of electronic concepts and practices, including this program on the basics of digital electronics. Available from: Tel-A-Train; P.O. Box 4752; Chattanooga, TN 37405; 800-266-0113.
- *Logical or Boolean Expressions.* Although designed primarily for college engineering students, this program covers the basics of Boolean algebra and types of gates and should be suitable for most upper high school and adult programs. Available from: Colorado State University; AV Services; Division of Continuing Education; Telecommunications Extended Studies; Ft. Collins, CO 80523.
- *Logic Arrays.* Suitable for advanced students or as general information about gate arrays. Available from: Massachusetts Institute of Technology; Video Courses CEC; 77 Massachusetts Ave.; Cambridge, MA 02139.

Software

- *Logic Circuits.* Covers the principles and operation of logic circuits. Available from: American Peripherals; 141 Cortland St.; Lindenhurst, NY 11757.
- *Logic Gates.* This is a 30-lesson series that allows students to work with simulations of the eight most common logic gates. Available from: MECC; 3490 Lexington Ave. North; St. Paul, MN 55126-8097.

Logic Devices and Circuits
Unit 1

Answers to Assignment Sheets

Assignment Sheet 1— Convert Octal Numbers to Decimal Numbers

1. 256
2. 423
3. 20
4. 1099
5. 3001
6. 219
7. 43,007
8. 302
9. 10,501
10. 148,371

Assignment Sheet 2— Convert Decimal Numbers to Octal Numbers

1. 60
2. 14,500
3. 500
4. 12,431
5. 1747
6. 27,453
7. 1,345,726
8. 4201
9. 345
10. 2525

Assignment Sheet 3— Convert Decimal Numbers to Binary Numbers

1. 1001010
2. 10111010
3. 1000101011
4. 10010111110
5. 10111110111011
6. 1111101000
7. 11111
8. 100100100111110000000
9. 1100011
10. 11111100100

Assignment Sheet 4—Convert Binary Numbers to Base Ten Numbers

1. 2
2. 7
3. 13
4. 17
5. 117
6. 129
7. 27
8. 31
9. 5
10. 391

Assignment Sheet 5—Use the Double-Dabble Method to Convert Binary Numbers to Decimal Numbers

1. 5
2. 51
3. 36
4. 109
5. 257
6. 258
7. 127
8. 183
9. 152
10. 136

Answers to Assignment Sheets

Assignment Sheet 6—Convert Binary Numbers to Octal Numbers

1. 2
2. 7
3. 15
4. 21
5. 73
6. 100
7. 707
8. 25
9. 61
10. 254

Assignment Sheet 7—Convert Octal Numbers to Binary Numbers

1. 1001111111
2. 1000001000
3. 101110
4. 11011001101100
5. 1001001000000001
6. 111111100001
7. 101010101010101
8. 11000010
9. 10111
10. 10010010010010

Assignment Sheet 8—Convert Binary Numbers to Hexadecimal Numbers

1. 3C
2. CD
3. 57
4. 28
5. F1
6. D4
7. 40
8. 77
9. F
10. 2AA

Assignment Sheet 9—Convert Hexadecimal Numbers to Binary Numbers

1. 11111
2. 111110
3. 111010
4. 100001
5. 101000
6. 10000100
7. 11000011
8. 1110111
9. 101010101010
10. 100101101

Assignment Sheet 10—Complete Logic Tables

1. a. 0
   b. 0
   c. 0
   d. 0
   e. 0
   f. 0
   g. 0
   h. 1
   i. 1
   j. 0
   k. 0
   l. 0
   m. 0
   n. 0
   o. 0
   p. 0

Answers to Assignment Sheets

2.	a.	1	i.	0
	b.	1	j.	1
	c.	1	k.	1
	d.	1	l.	1
	e.	1	m.	1
	f.	1	n.	1
	g.	1	o.	1
	h.	0	p.	1
3.	a.	1	i.	0
	b.	0	j.	1
	c.	0	k.	1
	d.	0	l.	1
	e.	1	m.	0
	f.	1	n.	0
	g.	1	o.	0
	h.	1	p.	0

Assignment Sheet 11—Apply Boolean Operations to Minimizing Logic Circuits

1. $A = Y$
2. $(AB) + BCD$
3. $(AB) + (\bar{B}C)$
4. $(AB) + B + C + (CD)$
5. $(\bar{A} \oplus \bar{B})$
6. $ACD + BCD$
7. ABC
8. $\overline{ABC}D$
9. $\bar{A}B + \bar{A}B\bar{C}$
10. $\bar{A}B\overline{CD}$

Logic Devices and Circuits
Unit 1

Answers to Written Test

1.

a.	11	e.	2	i.	12	m.	7
b.	10	f.	15	j.	8	n.	1
c.	4	g.	3	k.	16	o.	13
d.	14	h.	6	l.	5	p.	9

2.

a.	Directly	i.	Permanent
b.	Indirectly	j.	Power
c.	Command and control	k.	Permanent
d.	Commands	l.	Active
e.	Control	m.	Active
f.	Data	n.	5, 0
g.	Pulse, pulses	o.	Serially
h.	Transmitted	p.	Parallel

3.

a.	1	d.	4
b.	3	e.	5
c.	6	f.	2

4.

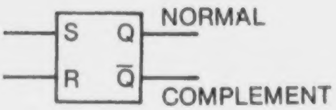
a.	6	d.	2	g.	7
b.	4	e.	5		
c.	1	f.	3		

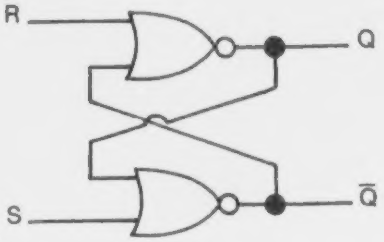
5.
- a. NOT gate (inverter)
- b. AND gate
- c. NAND gate (NOT AND)
- d. OR gate
- e. NOR gate (NOT OR)
- f. XOR gate (exclusive OR)
- g. XNOR gate (exclusive NOT OR)

6.

a.	A	e.	M	i.	B	m.	M
b.	B	f.	B	j.	A		
c.	M	g.	B	k.	A		
d.	A	h.	M	l.	B		

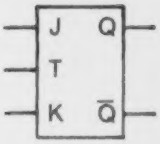
7.

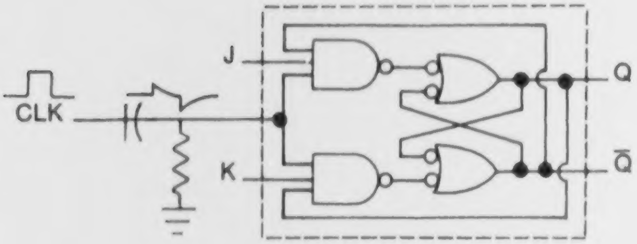




Answers to Written Test

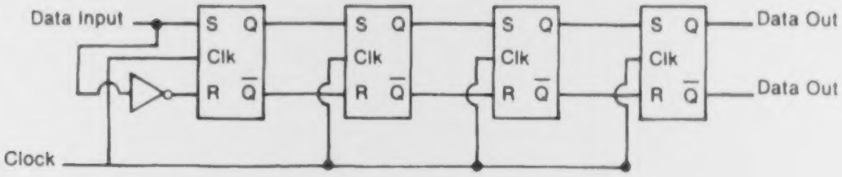
8.





9.
a. 3 d. 6 g. 2
b. 7 e. 5
c. 1 f. 4

10.



11. (Answer should include any 3 of the following)
    a. Perform arithmetic operations
    b. Parallel to serial data conversion
    c. Serial to parallel data conversion
    d. Counting
    e. Frequency dividing functions

12.
    a. Bistable
    b. Time delay
    c. Square
    d. RC
    e. Multivibrator
    f. Monostable
    g. Astable

13. (Answer should include any 3 of the following)
    a. To set the delay time between events
    b. To set the duration of events
    c. To maintain synchronization of circuits
    d. To record the time of occurrence of an event
    e. To record the duration of an event
    f. To present current time

14. a, b, d, e, f, g, i

Answers to Written Test

15.
- a. Several
- b. Time, frequency
- c. Radio
- d. Time
- e. Output
- f. Channel
- g. Sequentially
- h. Slot
- i. Number of times
- j. Speed
- k. Direct
- l. Parallel
- m. Pyramidal
- n. Two-level
- o. TDM
- p. Height
- q. Distorted
- r. Coded
- s. Demultiplexing

16.
- a. 3
- b. 4
- c. 1
- d. 2

17.
- a. The purpose of an encoder is to convert a signal characteristic into a specific code, such as amplitude into binary code.
- b. The purpose of a decoder is to convert a coded signal into its characteristic signal, such as converting a binary code into a sine wave.
- c. One of the most common ways of encoding is to use a multiplexed signal and assign coded values for several positive and negative levels of amplitude.
- d. By doing the same translation in reverse, a decoder is able to convert the coded signal back into the multiplexed signal.

18.
- a. Either internally or externally
- b. Transient
- c. Components
- d. Parallel
- e. Grounding
- f. Power supply
- g. Fan-in
- h. Fan-out
- i. Fast

19.
- a. ECL
- b. ECL
- c. TTL
- d. MOS
- e. CMOS
- f. ECL
- g. CMOS
- h. CMOS
- i. MOS
- j. TTL
- k. MOS
- l. ECL
- m. TTL
- n. MOS
- o. CMOS
- p. MOS

20.
- a. 5
- b. 1
- c. 4
- d. 2
- e. 3
- f. 6

21.
- a. 3
- b. 4
- c. 5
- d. 1
- e. 2
- f. 6
- g. 7

Logic Devices and Circuits
Unit 1

Written Test

Name ________________________________ Date ____________ Score ____________

1. Match terms associated with logic devices and circuits to their correct definitions. Write the corresponding numbers on the blanks provided.

______a. Method of transmitting signals in which several signals are sent at the same time through separate conductors

______b. An oscillator that does not produce a sinusoidal output waveform

______c. To sequentially decrease, as in counting backwards from 10 to 0 by ones

______d. Circuit in which timing depends on a master clock signal

______e. A single digit (binary 0 or 1) used to transmit or store information in an electronic logic or computer system

______f. Type of memory in which the information is lost if power is removed from the circuit

______g. Group of bits—usually eight—that represents a single character or symbol

______h. To sequentially increase, as in counting from 2 to 20 by twos

______i. Method of transmitting signals in which signals are sent one after another through a single conductor

______j. System of relationships that defines how a set of input signals is related to a set of output signals

______k. Group of bits or bytes that represent a complete element of information

1. Asynchronous
2. Bit
3. Byte
4. Decrement
5. Gate
6. Increment
7. Inverse
8. Logic
9. Memory
10. Multivibrator
11. Parallel transmission
12. Serial transmission
13. Shift register
14. Synchronous
15. Volatile memory
16. Word

Written Test

______l. Electronic device that allows input signals to enter and then manipulates them in a prescribed way to produce a single output

______m. In a mathematical set, an opposite

______n. Circuit in which timing depends on the relationship of the elements of the circuit rather than on a master clock signal

______o. Circuit that is capable of storing data or sending it to another, usually adjacent, device

______p. In electronic devices such as calculators and computers, the areas of the device where information can be stored

2. Complete statements about how signals represent information. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

   a. A signal may be used to represent information (directly, indirectly) as a result of its characteristics, such as polarity, voltage, frequency, etc.

   b. A signal may be used to represent information (directly, indirectly) so that an individual characteristic or a combination of its characteristics represents a symbol, such as a number, letter, computational sign, etc.

   c. The information carried by a signal is either ____________________ information or *data*.

   d. _______________ are instructions that tell equipment what functions to perform.

   e. _______________ information includes signals that influence other signals as a result of the equipment's operating conditions.

   f. _______________ is information that represents language, quantities, images, sound, and other symbols not related to the operation of the equipment.

   g. Information may be a single _______________ or a string of _______________.

   h. Information may be stored, maintained active, or _______________.

   i. Stored Information may be *volatile* or _______________.

   j. Information stored in volatile memory is lost once _______________ is removed.

k. Information stored in ______________ memory can be recovered after power has been removed once power is restored.

l. Information that is maintained in an (active, archived) state continues to receive power as a signal.

m. ______________ signals can be combined and routed through various devices so that the output of the device is related to the input signals or to some standard in a specific way that is defined as *logic*.

n. In binary logic circuits, signals that are basically *on* signals over approximately ______________ volts are termed *logic high* and represent binary 1, while signals near ______________ are termed *logic low* and represent binary 0.

o. Information may be transmitted ______________—that is, one pulse at a time.

p. Information may be transmitted in ______________—that is, several signals are transmitted along separate conductors at the same time.

3. Match numbering systems used with logic circuits to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Numbering system consisting of the symbols 0 and 1 arranged in seven-bit elements that represent the 26 lowercase letters, 26 uppercase letters, 10 decimal digits, and several special characters, such as punctuation symbols, monetary symbols, and other characters found on a keyboard

______b. Numbering system consisting of the symbols 0 and 1

______c. Numbering system consisting of the symbols 0, 1, 2, 3, 4, 5, 6, and 7

______d. Numbering system consisting of the symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9

______e. Numbering system consisting of the symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F

______f. Numbering system consisting of the symbols 0 and 1 arranged in four-bit elements that represent each decimal digit

1. American Standard Code for Information Interchange (ASCII)
2. Binary coded decimal system (BCD or 8421)
3. Binary system
4. Decimal system
5. Hexadecimal system
6. Octal system

Written Test

4. Match types of logic gates to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Combines two or more inputs to produce a single output that will be logic low unless all of the input are the same (high or low)

______b. Provides an output that is the inverse or complement of the input

______c. Combines two or more inputs to produce a single output that will be logic low unless all of the inputs are logic high

______d. Combines two or more inputs to produce a single output that will be logic low only when all of the inputs are logic high

______e. Combines two or more inputs to produce a single output that will be logic low unless the input signal contains one or more logic highs

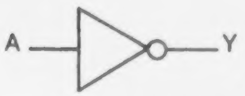
______f. Combines two or more inputs to produce a single output that will be logic low unless all of the input signals are logic low

______g. Combines two or more inputs to produce a single output that will be logic low when all input signals are the same (high or low)

1. AND gate
2. NAND gate
3. NOR gate
4. NOT gate
5. OR gate
6. XNOR gate
7. XOR gate

5. Label logic gate symbols.

a. ______________________________

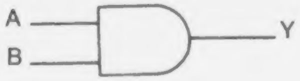


$\overline{A}=Y$

A	Y
0	1
1	0

Written Test

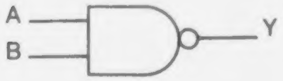
b. ______________________________



$AB=Y$

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

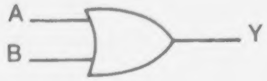
c. ______________________________



$\overline{AB}=Y$

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

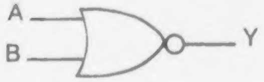
d. ______________________________



$A + B = Y$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

e. ______________________________

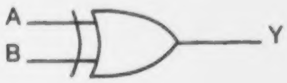


$\overline{A + B} = Y$

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Written Test

f. ______________________________

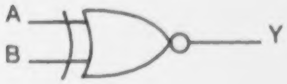


$\overline{A}B + A\overline{B} = Y$

$A \oplus B = Y$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

g. ______________________________



$\overline{A \oplus B} = Y$

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

6. Distinguish types of multivibrator circuits by their characteristics. For each characteristic listed below, write an "A" if the statement applies to astable multivibrators, a "B" if it applies to bistable multivibrators, and an "M" if it applies to monostable multivibrators.

______a. Free-running or clock

______b. Flip-flop

______c. One-shot

______d. Will remain in each state for a short period of time that is adjustable through design

______e. Have one stable output state

______f. Are the most widely used in memory and logic circuits

______g. Have two stable states

______h. Are used for delay circuits, timing circuits, and for waveshaping

Written Test

______i. Will remain in one of its stable states until triggered to switch

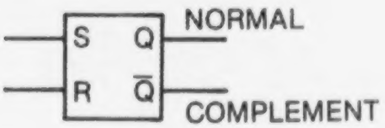
______j. Produce a rectangular waveform that switches back and forth between a fixed low and a fixed high state

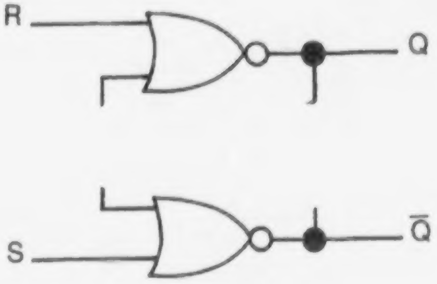
______k. Used primarily for timing devices and square wave generators

______l. Are used for counters, shift registers, and storage circuits

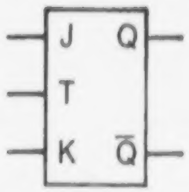
______m. Can be switched from its stable state for a short period but will quickly return to the stable state on its own

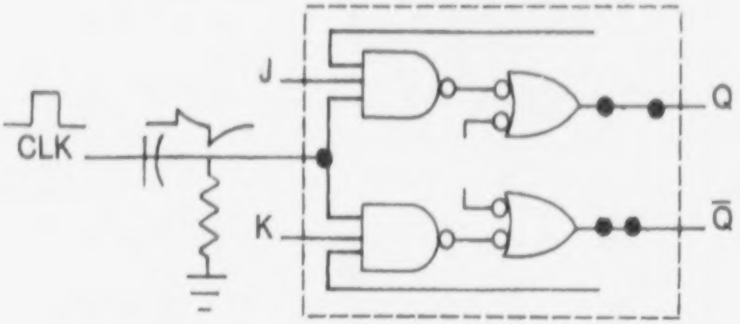
7. Complete a diagram of a set-reset flip-flop. Draw the lines necessary to show the proper connections for a set-reset flip-flop in the schematic below.





8. Complete a diagram of a J-K flip-flop. Draw the lines necessary to show the proper connections for a J-K flip-flop in the schematic below.





Written Test

9. Match types of counters to their correct descriptions. Write the corresponding numbers on the blanks provided.

_______a. The output frequency of each element is one-half of its input

_______b. Each element in the circuit is controlled by the same timing input

_______c. The elements, such as flip-flops, are cascaded so that the output of one device drives the next

_______d. Increases the count by one with each input pulse

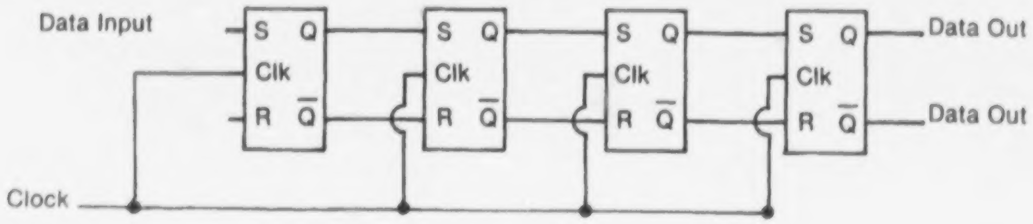
_______e. Counts down instead of up with each input pulse

_______f. Counts either up or down depending on the input from a count control signal

_______g. Has ten discrete states that represent the decimal numbers 0 through 9

1. Asynchronous counter
2. BDC counter
3. Binary counter
4. Combination counter
5. Decremental counter
6. Incremental counter
7. Synchronous counter

10. Complete a diagram of a shift register. Draw the lines and components necessary to show the proper connections for a shift register in the schematic below.



Written Test

11. List three functions that can be performed by shift registers.

    a. ______________________________

    b. ______________________________

    c. ______________________________

12. Complete statements regarding the operation of timing circuits. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. The 555 timer consists of two comparators, (an astable, a bistable, a monostable) multivibrator, a resistor voltage divider, a discharge transistor, and an output amplifier.

    b. The timer can be configured for ________________ or multivibrator operation.

    c. The timer's output will be a digital, (sine-, square-) wave signal in any configuration.

    d. The time-delay configuration is achieved with an external ________________ circuit and may include a transistor for triggering with time delays of microseconds to hours possible.

    e. ________________ operation may be monostable or astable free-running.

    f. The (astable, monostable) multivibrator is configured much like the delay timer without the transistor trigger because triggering is achieved when the input signal drops below one-third of the collector voltage supply of the internal transistor.

    g. The (astable, monostable) multivibrator is configured with the threshold and trigger pins directly coupled so that the external capacitor charges through both external resistors when the internal transistor is switched on and discharges through R_2 when the transistor is off.

13. List three functions of clock and timing circuits.

    a. ______________________________

    b. ______________________________

    c. ______________________________

Written Test

14. Select from a list functions of arithmetic-logic circuits. Write an "X" beside each item listed below that is a correct function of arithmetic-logic circuits.

______a. Addition

______b. Multiplication

______c. Logarithms

______d. Subtraction

______e. Division

______f. Computing the square root of a number

______g. Boolean algebra

______h. Euclidean geometry

______i. Computing the square of a number

15. Complete statements regarding the operation of multiplexer circuits. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Multiplexing is the process of transmitting through the air or over a link ________________ signals at the same time.

b. The two main methods for achieving multiplexing are ________________-division multiplexing and ________________-division multiplexing.

c. Frequency-division multiplexing is commonly used for modulated ________________ transmissions to allow simultaneous broadcast of the carrier and sideband signals.

d. Digital transmissions over hard links are usually multiplexed through (time, frequency)-division.

e. In semiconductor multiplexer circuits, input devices share a common (input, output) and clock pulses regulate TDM transmissions.

Written Test

f. For each clock pulse, one device has an open _______________ and its output is carried over the transmission link.

g. During the next clock pulse, another device transmits its output signal, and the process continues with each active input device being enabled (sequentially, simultaneously) by the clock pulses.

h. The period during which a device may transmit is called its time _______________.

i. The ____________________ that a single channel has a time slot within a given period, such as a second or microsecond, is called the *sampling frequency* or *sampling rate*.

j. Multiplexers can be configured so that some signals are sampled more often than others to allow for differences in signal (speed, strength) or importance.

k. _______________ coupling configures the multiplexers so that the output of one serves as the input to a second and the circuit output is the output of the second mux.

l. _______________ configuration uses a counter circuit to enable the multiplexers in succession so that the circuit output signal comes from one mux at a time in rotation.

m. _______________ configuration uses two banks of muxes and two counters so that the first counter controls the outputs of the first bank of muxes, which serve as the inputs to the second bank of mux(es) whose output is controlled by the second counter.

n. _______________ configuration uses two banks of muxes with each mux in the first bank being controlled by a different counter so that the time slot moves from mux to mux for one signal each with their output going to the second bank of muxes.

o. The two common ways of conditioning signals for (TDM, FDM) are pulse amplitude modulation and pulse code modulation.

p. In pulse amplitude modulation, the _______________ and polarity of the signal at the time of sampling is transmitted and is referred to as the *instantaneous amplitude*.

Written Test

q. The major drawback of PAM is that if the multiplexed signal becomes _______________ during transmission, then the output will provide the wrong information.

r. PCM overcomes this problem by converting pulse amplitude into a _______________ value, which is transmitted to represent the amplitude.

s. _______________ is the conversion of the signals at the other end of the transmission link.

16. Match types of analog/digital conversion circuits to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Uses an internal one-bit analog-to-digital converter tied to the output of a series integrator and comparator to provide a feedback signal to the integrator and whose final output is filtered to provide an average of the internal digital pulses; provides good speed while recognizing very low input signal levels with good resolution

______b. Compares analog input voltage to internal reference voltage divider tap and generates a digital output each time a match is obtained between the input and the reference signal; moderately fast

______c. Uses integrator and comparator networks to convert a monitored input signal to a digital output based on the time it requires the integrator output to return to a reference voltage level, such as 0 volts; provides good noise immunity but is relatively slow

______d. Uses two clock signals and a network of 256 resistors and comparators to provide simultaneous conversion; very fast conversion but requires space and power

1. Dual-slope
2. Flash
3. Sigma-delta
4. Successive approximation

Written Test

17. Describe the operation of encoder/decoder circuits. For each key word or phrase given below, describe the related operational characteristic of an encoder/decoder circuit.

    a. Purpose of encoder—______________________________
    ____

    b. Purpose of decoder—______________________________
    ____

    c. Common method of digital coding—______________________________
    ____

    d. Operation of decoder—______________________________
    ____

18. Complete statements regarding noise problems. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. Digital circuits can experience problems as a result of (internally, externally, either internally or externally) generated noise.

    b. Noise may be static or ______________.

    c. Internally generated noise may result from the relationship of ______________ to each other.

    d. Internally generated noise may result from circuit board traces being too close to each other or because of traces running (parallel, perpendicular) to each other.

    e. Internally generated noise may result from poor or improper (grounding, encoding).

    f. Many logic circuit noise problems result from the circuit (power supply, encoder).

    g. One method of reducing power-supply induced noise is to use a (fan-in, fan-out) power distribution, which provides separate power traces to a group of ICs.

    h. Another method of reducing power-supply induced noise is (fan-in, fan-out) distribution, which routes power to a single IC and then to other ICs in that group.

    i. Noise can also result from trying to drive a digital circuit too (fast, slowly), which increases the power requirements and reduces the resolution of the analog input.

Written Test

19. Distinguish common IC logic families by their characteristics. Write the abbreviation from the list below that applies to each statement in the space beside the statement.

- TTL for transistor-transistor logic
- ECL for emitter-coupled logic
- MOS for metal-oxide semiconductor
- CMOS for complementary-metal-oxide semiconductor

______a. Uses nonsaturating bipolar transistors

______b. Moderate cost

______c. Costs relatively little

______d. Simple construction

______e. Overall characteristics generally well balanced

______f. Relatively high power consumption

______g. Low power consumption

______h. Excellent noise immunity

______i. Permits construction of small circuits

______j. Uses two transistors often in a bipolar IC

______k. High impedance

______l. High speed

______m. Used in a wide variety of devices

______n. Relatively slow speed

______o. Fairly high speed

______p. Relatively low power consumption

73

Written Test

20. Match characteristics of electronic displays to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Ability of the display to maintain an output that does not flicker or float about the display area

______b. Amount of light produced by the display

______c. Degree to which fine details can be duplicated on the display

______d. Degree to which adjacent areas of a display can be distinguished from each other

______e. Measurement of how many dots of light are used to create the display picture

______f. Range of perspectives from which an operator can read a display

1. Brightness
2. Contrast
3. Pixels per inch
4. Resolution
5. Stability
6. Viewing angle

21. Match types of displays to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Used for portable computers, portable video games, and other devices where color is more important than contrast and brightness; generally consists of pixel clusters of red, blue, and yellow (or green) that combine to make a single point of light so that resolution is limited

______b. Used for calculators, watches, and other devices where power and cost may be limited and resolution, brightness, contrast, and color are not important

______c. Used for clock radios, portable computers, and other devices where power and cost are less restricted and moderate brightness is required; usually presented in red, amber, green, or gray and capable of high contrast

1. Active matrix liquid crystal display
2. Cathode ray tube
3. Color liquid crystal display
4. Light-emitting diode display
5. Monochrome liquid crystal display
6. Pixie tube
7. Seven-segment display

Written Test

______d. Used for portable computers, instrumentation displays, and other devices where high contrast and resolution are required; uses enhanced lamp drivers that allow greater control of individual pixels

______e. Used in televisions, test equipment, computers, and other devices where size and power are not as restricted as with most portable equipment

______f. Used to provide numerical readouts for some test equipment and instrumentation; consists of a gas-filled tube having ten cold cathodes under a disk-shaped anode so that a different digit is illuminated with each cathode as current shifts from one to another

______g. Used to provide numerical readouts in various devices; usually constructed with LEDs or LCDs

*Permission to duplicate this test is granted.

Logic Devices and Circuits
Unit 1

Unit Evaluation Form

Student Name ______________________________ Unit Rating ____________

Assignment Sheet Ratings

Assignment Sheet 1—Convert Octal Numbers to Decimal Numbers Rating ____

Comments: ______________________________

Assignment Sheet 2—Convert Decimal Numbers to Octal Numbers Rating ____

Comments: ______________________________

Assignment Sheet 3—Convert Decimal Numbers to Binary Numbers Rating ____

Comments: ______________________________

Assignment Sheet 4—Convert Binary Numbers to Base Ten Numbers Rating ____

Comments: ______________________________

Assignment Sheet 5—Use the Double-Dabble Method to Convert Binary Numbers to Decimal Numbers Rating ____

Comments: ______________________________

Assignment Sheet 6—Convert Binary Numbers to Octal Numbers Rating ____

Comments: ______________________________

Unit Evaluation Form

Assignment Sheet 7—Convert Octal Numbers to Binary Numbers Rating _____

Comments: ____

____

Assignment Sheet 8—Convert Binary Numbers to Hexadecimal Numbers Rating _____

Comments: ____

____

Assignment Sheet 9—Convert Hexadecimal Numbers to Binary Numbers Rating _____

Comments: ____

____

Assignment Sheet 10—Complete Logic Tables Rating _____

Comments: ____

____

Assignment Sheet 11—Apply Boolean Operations to Minimizing Logic Circuits Rating _____

Comments: ____

____

Job Sheet Ratings

Job Sheet 1—Construct and Test an "AND" Gate Circuit Rating _____

Comments: ____

____

Job Sheet 2—Construct and Test an "OR" Gate Circuit Rating _____

Comments: ____

____

Unit Evaluation Form

Job Sheet 3—Construct and Test a "NAND" Gate Circuit Rating ______

Comments: ______________________________

Job Sheet 4—Construct and Test a "NOR" Gate Circuit Rating ______

Comments: ______________________________

Job Sheet 5—Construct and Test an "Exclusive-OR" Gate Circuit Rating ______

Comments: ______________________________

Job Sheet 6—Construct and Test a Four-Bit Shift Register Rating ______

Comments: ______________________________

Job Sheet 7—Construct and Test a Flip-Flop Circuit Rating ______

Comments: ______________________________

Job Sheet 8—Construct and Test a J-K Counter Circuit Rating ______

Comments: ______________________________

Job Sheet 9— Construct and Test an A/D Converter Rating ______

Comments: ______________________________

Job Sheet 10— Construct and Test a D/A Converter Rating ______

Comments: ______________________________

Unit Evaluation Form

Job Sheet 11— Construct and Test a BCD to Seven-Segment Decoder Rating _____

Comments: ____

____

Job Sheet 12—Troubleshoot Logic Circuits Rating _____

Comments: ____

____

Written-Test Scores

Pretest _______ Posttest _______ Other _______

Other ____

____

Teacher Signature ________________________________ Date ______________

Student Signature ________________________________ Date ______________

*Permission to duplicate this form is granted.

Logic Devices and Circuits
Unit 1

Supplement 1—Boolean Algebra

Introduction Your students are likely to have varying degrees of math skills. Some may be intimidated by long division, so that the term *algebra* is likely to severely increase their anxiety levels. When confronted with the theorems and strange signs used in Boolean algebra, even some of your more math-literate students are likely to cringe a bit.

You will have to decide for yourself the degree to which you want your students to master Boolean algebra. This unit of instruction mentions Boolean algebra as one of the mathematical functions that can be performed by logic devices and includes one assignment sheet in which the students apply Boolean algebra. Neither of those activities is designed to make the students competent in this type of math. Specifically, the assignment sheet assumes that the student knows the Boolean equation associated with each logic device and can apply Boolean and DeMorgan theorems to solve the combinational logic problems that are presented. Therefore, students must master the basics of Boolean algebra in order to do the assignment sheet. This supplement is intended to provide you with the resources necessary to teach those fundamentals or to provide the students with the information they need to know in order to apply Boolean algebra to logic circuits. The introduction to the assignment sheet provides some historical background about Boolean algebra and how it became associated with electronics, so this supplement jumps right into the heart of Boolean operations.

Directions Use the information in this supplement and in other resources to teach Boolean algebra as it applies to logic circuits. You may use the information as teaching aids or copy it for distribution to the students. If distributed to students, the material can serve as a reference to support your presentation or as a self-study guide for independent learning. Modify the supplement as necessary to tailor it to the specific material that you want to present.

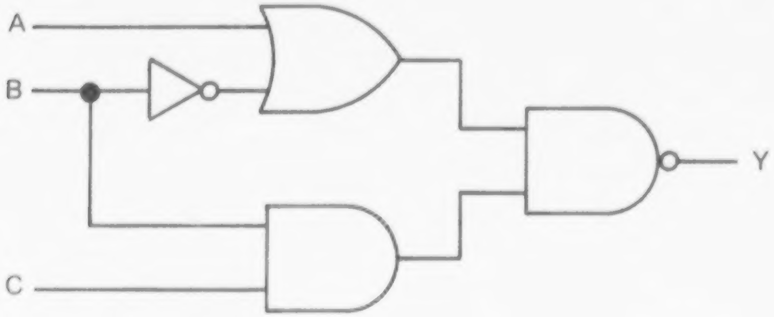
Supplement 1

Boolean Algebra

Introduction

Boolean algebra is a tool used by electronics engineers and technicians. One use of the tool is to simplify combinational logic circuits. It can be difficult to keep track of the binary value of a signal, especially when it is the product of many input signals that have passed through a variety of logic devices. Boolean algebra is a mathematical system that is functional with given sets of elements. In digital electronics, the set of elements is the binary system, consisting of the elements 1 and 0. The limited size of the set helps to keep the system easy for electronics. Every operation will result in either a 1 or a 0.

Consider the circuit below:



To understand the output of this circuit, we can create a truth table for each logic device and determine the output of each device and use that as the input for the next device and determine its output and then go to the next device until we determine the final output. This process can be time-consuming, complicated, and confusing, and the incorrect determination of one output will cause the rest of the calculations to be wrong.

This is where Boolean algebra can be helpful with combinational logic circuits. Each logic gate can be represented by a Boolean equation and those equations can be combined and reduced to give one overall equation for the whole circuit. The answer to the reduced equation is the output of the whole circuit. This method is far easier than creating truth tables and tracking the signal changes through the circuit.

Operations

You are familiar with a number of mathematical operations, such as adding, subtracting, dividing, squaring, averaging, etc. In Boolean algebra, there are only two operations. The first operation is associated with the AND logic gate and is normally referred to in electronics as the AND operation or AND function. It is represented in different texts by a variety of symbols, including ⊗, ×, ∧, ∩, ·, or **O** and is quite often written

Supplement 1

without a symbol. Thus, for an AND gate with input A and input B, the equation would be:

$$A \otimes B = Y \qquad \text{or} \qquad AB = Y,$$

where Y is the output. Before we look at what this equation does in terms of the binary set, let's consider the other operation.

The second Boolean operation in digital electronics is represented by the OR gate and uses any of the following symbols: $\oplus$, $+$, $\vee$, or $\cup$. Thus, a two-input OR operation would be shown by the equation:

$$A \oplus B = Y \qquad \text{or} \qquad A + B = Y$$

In this course, we write the AND function as *AB* and the OR function as *A + B* when the connection to logic gates is clear.

Relationships

Any two elements in Boolean algebra within the binary set are related in one of two ways. They can both be the same value. In this case, they are said to be equal and their relationship is symbolized by an equal sign. Thus, if A and B have the same value, then the equation to show their relationship is

$$A = B$$

The other Boolean binary relationship is called *nonequality* or, more often, *complement*. The symbol for a complement of a value is the symbol for that value with a line over it. Thus, the complement of A would be written as $\overline{A}$. In the binary system, 1 is the complement of 0 and 0 is the complement of 1, so you may have already figured out that the action of an inverter logic gate produces a complement. Consequently, the equation for an inverter is

$$A = \overline{A}$$

Before we go on, here is a word of caution about the equal sign. As you can see from the past few examples, the equal sign is used both to describe the relationship of equality, as in A = B, and the result of a function, as in $A = \overline{A}$. This latter statement is not true of the relationship between the two values because in the binary system a value can never be its own complement. It is only true in terms of what an inverter does. In reality, the latter equation reads, "When input A passes through an inverter, the output signal is the complement of A." To make this clear, some texts may use symbols other than an equal sign to show logic gate equations so that the equation might use an arrow, for example, as in:

Supplement 1

$$A \oplus B \Rightarrow Y$$

In this course, we use the equal sign when showing equations and words such as "is equal to" or "is" when describing values of symbols. Thus, we would express the operation of a NOT gate (inverter) as:

$A = Y = \overline{A}$, so that if A is equal to 1, then Y is 0

Applying numbers

For many people, the easiest way to understand Boolean equations is to put them in terms of the binary numbers. This can be done fairly easily and consistently if one expresses all of the equations in terms of binary 1. Let's start with the NOT gate and the equation just given. The equation can be stated as "Whatever A is, Y will be its complement." Stating that in terms of 1, we would say, "Y will equal 1 only when A is 0."

Let's state the AND equation ($AB = Y$) in terms of an output of 1. "Y will be 1 only if A *and* B are 1." Compare this to the truth table and see if this is the case. For an AND gate, the output (Y) equals 1 only when all of the inputs are 1. If we use a three-input gate, then the equation would be $ABC = Y$, and Y would equal 1 only when A *and* B *and* C are 1.

This is also the case with the OR gate. The equation $A + B = Y$ represents an output of 1 only when *either* A *or* B is 1. Thus, "Y will be 1 only when A or B is 1 but not both are 1."

Other gates

So far we have looked at equations for three logic gates: NOT, AND, and OR. What about the others? How can they be handled if there are only two operations in Boolean algebra? In formal Boolean algebra, the two operations are enough to describe the results of other gate combinations. For example, the operation of a NAND gate is often expressed as

$$\overline{AB} = Y$$

and the operation of a NOR gate is expressed as

$$\overline{A + B} = Y$$

These equations are easily understood as saying that these gates produce the complement of the AND and OR gates respectively. For example, if AB produces a 1 output then $\overline{AB}$ will produce a 0 output, and if $A + B$ produces a 0 output then $\overline{A + B}$ will produce a 1 output. You can verify this in the truth tables. The output of a NAND gate is the complement of the output of an AND gate with the same inputs, no matter how many inputs there are.

Let's look at these two gates in terms of a 1 output. The NAND gate will produce a 1 output only if A and B are not both 1. Because the bar over the elements shows a complementary relationship, we state that "Y will be the complement of 1 only when A and B are 1." Of course this means that the result will be 0 only when A and B are both 1, and it is fine to remember it that way. However, by stating all the relationships in terms of an output of 1 or complement of 1 helps some people remember the relationships better.

With the NOR gate, "Y will be the complement of 1 only when either A or B is 1 but not both are 1."

The other two logic gates that you have studied are the exclusive-OR gate and the NOT exclusive-OR gate, which is also referred to as the exclusive-NOR gate. Thus far, we have created a unique equation for each gate by using the AND and OR relationship symbols and the complement bar. These equations are a convenient short hand in that there is no need to describe the associated gate or show its symbol. For the exclusive-OR and exclusive-NOR gates, we borrow one of the other Boolean symbols (⊕) to show the operation. The exclusive-OR equation can be written as

$$A \oplus B = Y = \overline{A}B + A\overline{B}$$

Try stating the result in terms of a 1 output. Your response should be "Y will be 1 if A is the complement of B or if B is the complement of A." This can be shortened to "Y will be 1 if A and B are complements."

The equation for the XNOR gate is

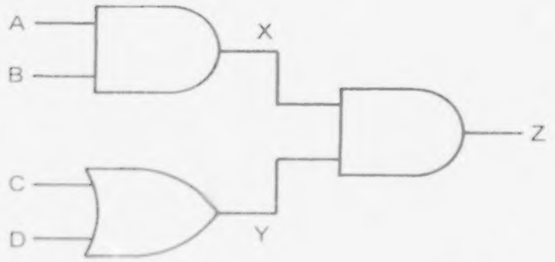
$$\overline{A \oplus B} = Y = \overline{\overline{A}B} + \overline{A\overline{B}}$$

To state the XNOR equation in terms of a 1 output, you would say, "Y will be the complement of 1 if A and B are complements."

Combinational logic

Now that you know the equations for individual gates, you can apply that knowledge to combinational circuits. Let's begin by looking at a circuit that has a two-input AND gate and a two-input OR gate fed into a second two-input AND gate as shown in the schematic on the next page.

Supplement 1



Signals A and B are combined in the first AND gate, the output of which can be expressed as AB = X. Signals C and D enter the OR gate, resulting in an output of C + D = Y. The second AND gate combines the outputs of the first two gates to produce XY = Z. However, we can gain a better understanding of what is happening electronically if we combine the equations as follows:

$$AB(C + D) = Z$$

Using the previously presented equations, we can summarize this one as:

Z will be 1 if AB and (C + D) are 1

AB will be 1 if A and B are 1

(C + D) will be 1 if A or B are 1

Thus, Z will equal 1 only when A and B and at least one other signal are 1. Knowing this, we can quickly create a truth table as shown below:

A	B	C	D	Z
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	1	0	0	0
1	0	0	0	0
0	0	1	1	0
0	1	1	0	0
1	1	0	0	0
0	1	0	1	0
1	0	1	0	0
0	1	1	1	0
1	0	1	1	0
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

Supplement 1

While this approach is helpful in allowing us to construct a truth table, our example was fairly simple. As the circuits become more complex, even this tool begins to bog down. For that reason, if Boolean algebra is to be helpful with more complex circuits, we need to apply the mathematics of Boolean algebra, which means using some of the theorems associated with Boolean algebra.

Theorems

A theorem is a statement that defines mathematical relationships. A total of 17 theorems are associated with Boolean algebra as applicable to logic circuits, but you will be glad to know that you have already learned most of them as part of this course or as part of other math courses that you have taken. The first eight Boolean theorems deal with single input circuits. They describe open and shorted circuits, with opens representing binary 0 and short circuits representing binary 1, and indicate the value that results when a signal is AND or OR combined with itself, its complement, a short (1), or an open (0). The resulting equations can be summarized as follows:

Theorem Number	Equation
1	$AA = A$
2	$A0 = 0$
3	$A + 1 = 1$
4	$A + \bar{A} = 1$
5	$A + A = A$
6	$A\bar{A} = 0$
7	$A1 = A$
8	$A + 0 = A$

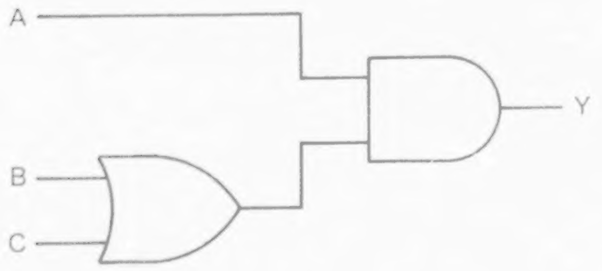
Theorems 9 and 10 are called the commutative laws and are the same as commutative laws in other branches of mathematics. Basically, a commutative law states that the order of the elements does not matter in a given mathematical operation. Thus, 2 + 3 is the same as 3 + 2, and 4 x 5 is the same as 5 x 4. This is also true of Boolean equations. AB is equal to BA, and A + B gives the same result as B + A.

Theorems 11 and 12 are the associative laws and also have equivalents in other branches of mathematics. This theorem states that it is possible to pair values in various ways as they undergo an operation without changing the result. This explains why (3 + 4) + 2 gives the same sum as 3 + (4 + 2) and why (1 x 5) x 3 gives the same product as 1 x (5 x 3). Addition and multiplication are subject to the associative law. In Boolean algebra, the AND operation A(BC) is the same as the AND operation (AB)C and the OR operation A + (B + C) is equivalent to the OR operation (A + B) + C.

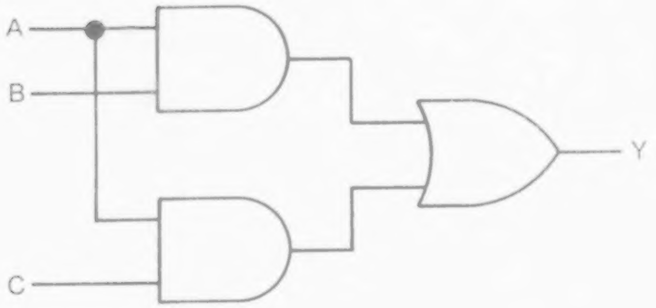
Supplement 1

The distributive law is Theorem 13. As in the multiplication and addition of decimal numbers where 2(3 + 2) is the same as (2 x 3) + (2 x 2), in Boolean algebra, A(B + C) is equal to AB + AC. These two equations represent the following circuits, and you should be able to demonstrate that each will lead to the same final output.

Circuit 1: A(B + C)



Circuit 2: AB + AC



The final two Boolean theorems that apply to logic circuits are similar to the distributive law. The equation for the first is

$$A + AB = A$$

Let's consider this in terms of A = 1. For A + AB to equal 1, the OR equation states if either A or AB is a 1, then the output will be 1. Clearly if A is 1, then it does not matter what AB is because one of the two elements is 1. Now if the output is to be 0, then A is zero, and for the statement to be true AB would also have to equal zero. Stating an AND gate in terms of 1, for the output to equal 1 then both A and B must equal 1. Since we know A is 0, then AB is also 0.

Supplement 1

The last Boolean equation we will study states

$$A + \overline{A}B = A + B$$

The proof of this is similar to what we worked out for the previous theorem. For the statement to be true, then $\overline{A}B$ must equal B. If we assume B to be 1, then $\overline{A}$ and B only equal 1 when both of them are 1. If we assume that B is 0, then $\overline{A}$ and B cannot equal 1 no matter what A or its complement are because B is 0.

DeMorgan's theorems

In addition to Boolean's theorems, two other theorems developed by logician and mathematician Augustus DeMorgan are particularly useful in simplifying logic circuits. The first states that the complement of an AND operation is equal to the OR operation of the complements. This is expressed by the equation

$$\overline{AB} = \overline{A} + \overline{B}$$

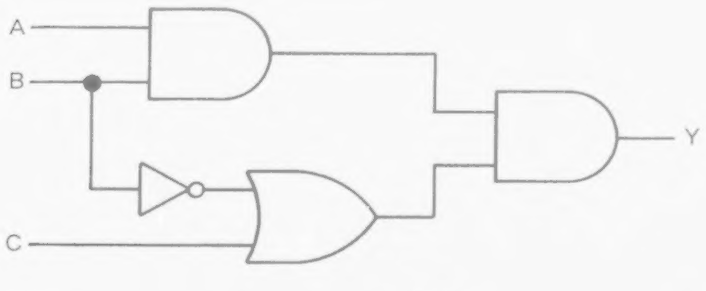
DeMorgan's second theorem is that the complement of an OR operation is equal to an AND operation of the complements. The expression for this relationship is

$$\overline{A + B} = \overline{A} \times \overline{B}$$

Examples

Now that we have presented the basics of Boolean algebra, a couple of examples of circuit reduction may be helpful. The objective of circuit reduction is to express the entire circuit as a single operation of inputs (two if possible) within a single equivalent logic device. This may sound impossible at first, but each logic device produces a single output leading to the last logic device with its single output. Everything that happens before that last device is only important in terms of how they have shaped the final set of inputs.

The circuit below has three inputs, one of which branches into an inversion. How can it be reduced?



Supplement 1

Begin by writing out the full equation. Show the equation for the first AND gate output combined with the output of the OR gate by the second AND gate:

$$AB(\overline{B} + C) = Y$$

Use the distributive law to reduce this equation to one operation.

$$AB\overline{B} + ABC = Y$$

We now have a single operation for the circuit, but the two elements in the operation can be reduced. On the left side, we can use the associative theorem for AND operations to regroup the three-signal element:

$$A(B\overline{B}) + ABC = Y$$

According to Theorem 6, ANDing a number with its complement results in a 0. So now we have a value to work with and rewrite the equation as

$$A0 + ABC = Y$$

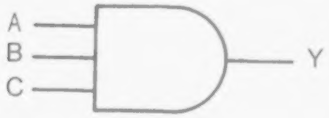
Theorem 2 tells us that any value ANDed with 0 results in 0, so we can replace the left element with 0. This gives us an OR operation with 0:

$$0 + ABC = Y$$

Theorem 8 states that ORing any value with 0 results in the value, which leaves us with

$$ABC = Y$$

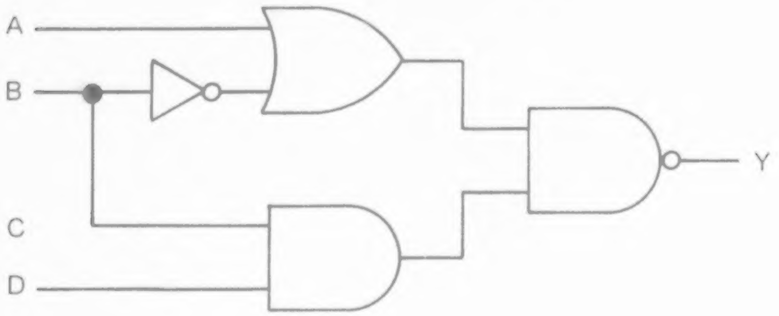
The circuit can actually be redrawn in a simplified form as:



If we know the values for the signals, we can determine the output. For example, assume that A is high and B and C are low. This would mean that we have an AND operation with inputs of 1, 0, and 0. The truth table for an AND gate shows that the output will be 0 unless all of the inputs are 1. Therefore, the circuit in this example has an output of 0.

Supplement 1

Our second example has three inputs as shown below.



Begin with the full circuit expression:

$$\overline{(A+\overline{B})\cdot(BC)} = Y$$

There are numerous ways to reduce any logic circuit using Boolean algebra, and no one way is necessarily the best as long as your way leads to the correct answer. But a good place to begin with this one is to apply DeMorgan's theorems to get rid of the overall inversions:

$$\overline{(A+\overline{B})} + (\overline{BC}) = Y$$

$$(\overline{A}B)\cdot(\overline{B}+\overline{C}) = Y$$

Applying the distributive theorem, we can convert the revised equation to

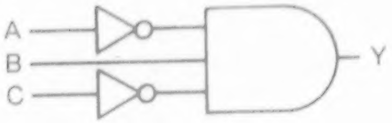
$$\overline{A}B\overline{B} + \overline{A}B\overline{C} = Y$$

According to Theorem 6, an AND operation with a value and its complement results in a 0, while Theorem 2 tells us that an AND operation between a value and 0 results in 0. Thus, we see that the left element is 0. Using Theorem 8, performing an OR operation with a value and 0 results in that value. Thus, our final equation is

$$\overline{A}B\overline{C} = Y$$

Supplement 1

The simplified circuit would be



Using Boolean algebra and applying the theorems as outlined here should allow you to reduce most combinational logic circuits without having to create a logic table for each operation in order to determine the final output.

91

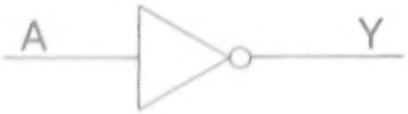
Binary to Decimal Conversions

A. $1011_2 = \overset{2^3}{\underset{(8)}{1}}\ \overset{2^2}{\underset{(4)}{0}}\ \overset{2^1}{\underset{(2)}{1}}\ \overset{2^0}{\underset{(1)}{1}} = (1x8)+(0x4)+(1x2)+(1x1) + 8+0+2+1 = 11_{(10)}$

B. $111_2 = \overset{2^2}{\underset{(4)}{1}}\ \overset{2^1}{\underset{(2)}{1}}\ \overset{2^0}{\underset{(1)}{1}} = (1x4)+(1x2)+(1x1) = 4+2+1 = 7_{(10)}$

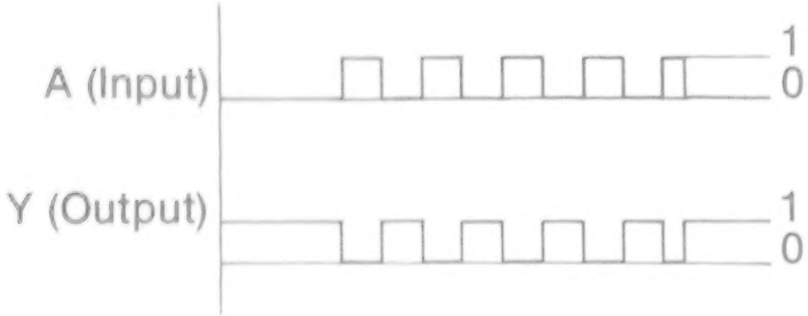
C. $11011_2 = \overset{2^4}{1}\ \overset{2^3}{1}\ \overset{2^2}{0}\ \overset{2^1}{1}\ \overset{2^0}{1} = (1x16)+(1x8)+(0x4)+(1x2)+(1x1) = 16+8+0+2+1 = 27_{10}$

NOT Gate (Inverter)



$\overline{A} = Y$

Symbol

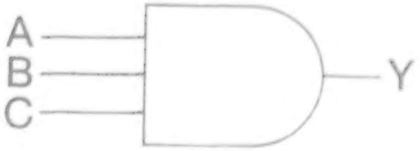


A	Y
0	1
1	0

Truth Table

0 = Logic Low   1 = Logic High

AND Gate



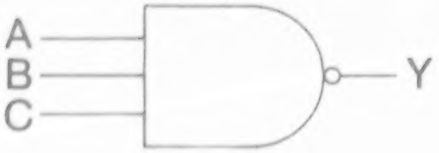
ABC = Y

Symbol

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

Truth Table

NAND Gate



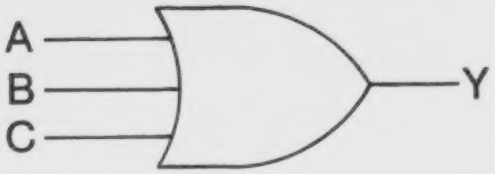
$\overline{ABC} = Y$

Symbol

A	B	C	Y
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Truth Table

OR Gate



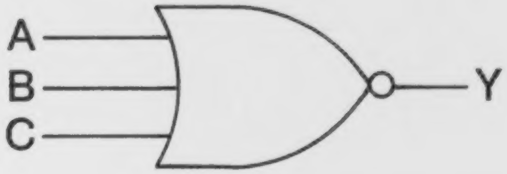
A+B+C=Y

Symbol

A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

Truth Table

NOR Gate



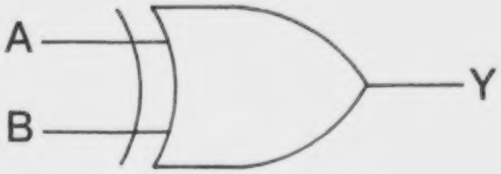
$\overline{A+B+C}=Y$

Symbol

A	B	C	Y
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

Truth Table

Exclusive OR Gate



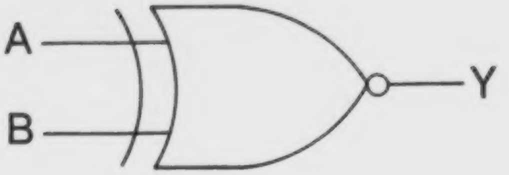
$A \oplus B = Y$

Symbol

A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

Truth Table

NOT Exclusive OR Gate



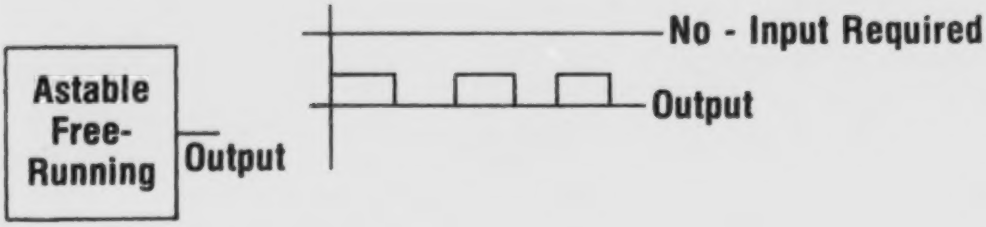
$\overline{A \oplus B} = Y$

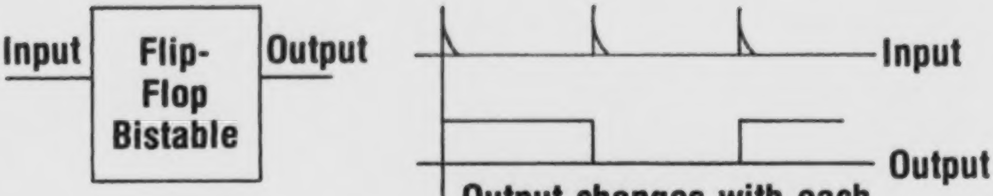
Symbol

A	B	$\overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

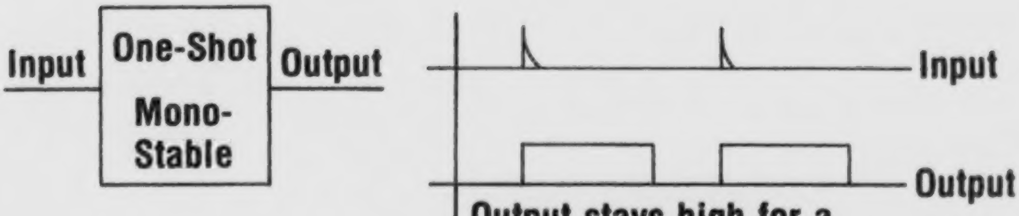
Truth Table

Multivibrators





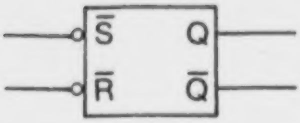
Output changes with each input pulse



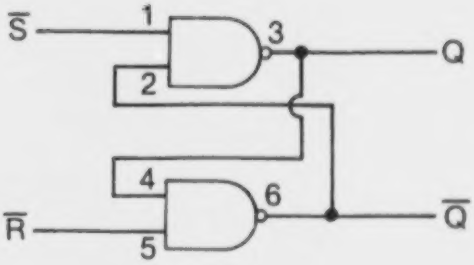
Output stays high for a period of time then goes back to its normally low state

Multivibrators may be made from either discrete devices or integrated circuits

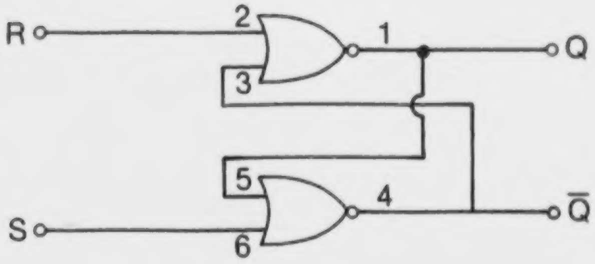
R-S Flip-Flop



Symbol

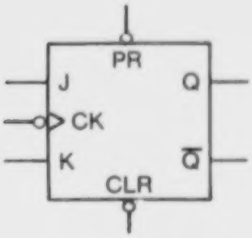


R-S Flip-Flop (NAND Gate Type)

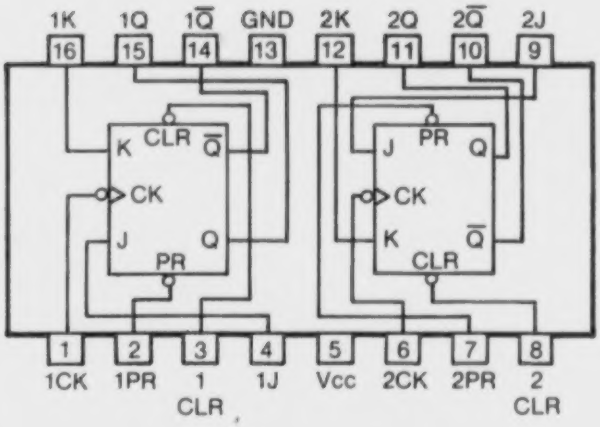


R-S Flip-Flop (NOR Gate Type)

J-K Flip-Flop



Symbol

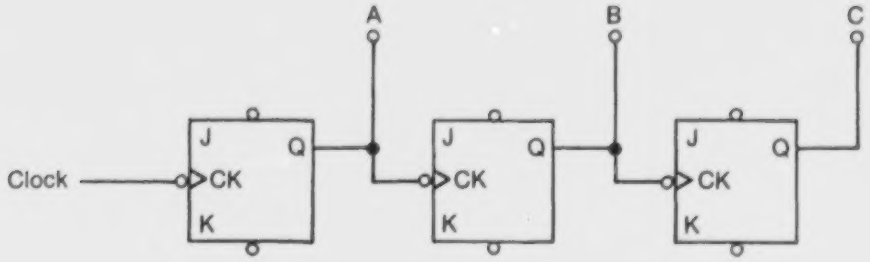


Pinout for 7476
dual J-K Flip-Flop

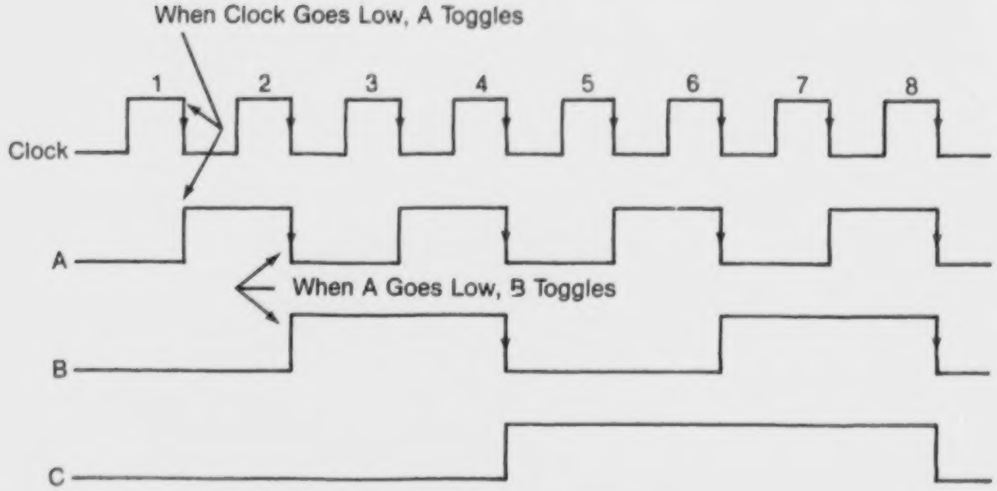
J	K	Mode	
0	0	Inhibit	Q output will not change when clocked
0	1	Reset	Q output will go low when clocked
1	0	Set	Q output will go high when clocked
1	1	Toggle	Q output will change to opposite state when clocked

Operation

Binary Counter

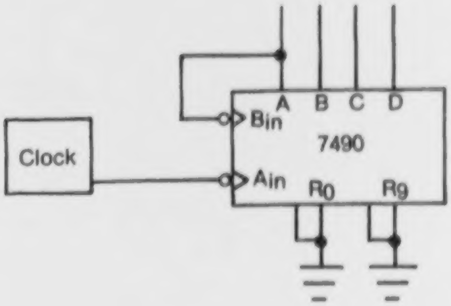


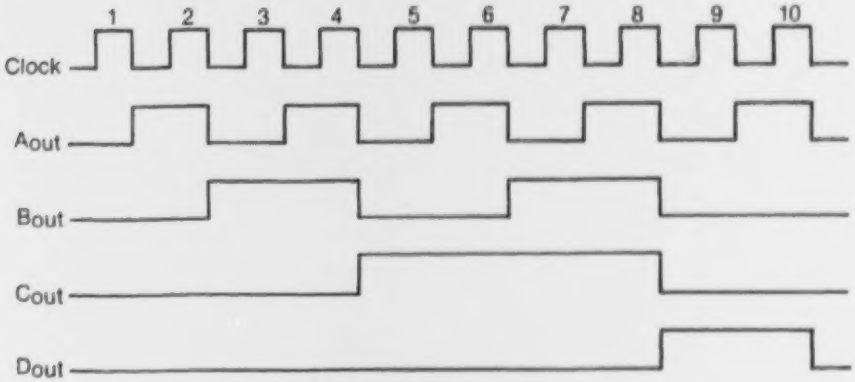
3 - Bit Binary Counter
Block Diagram



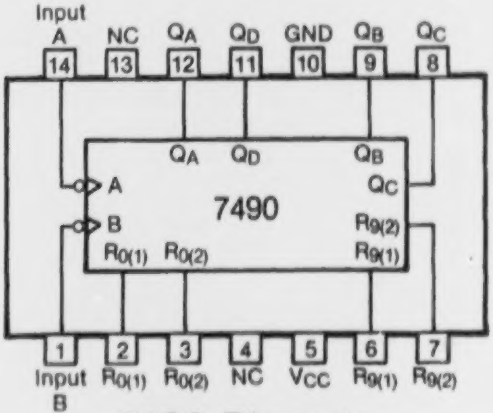
Output Waveforms

Decade Counter



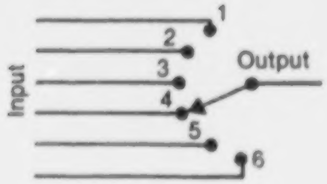


Waveforms

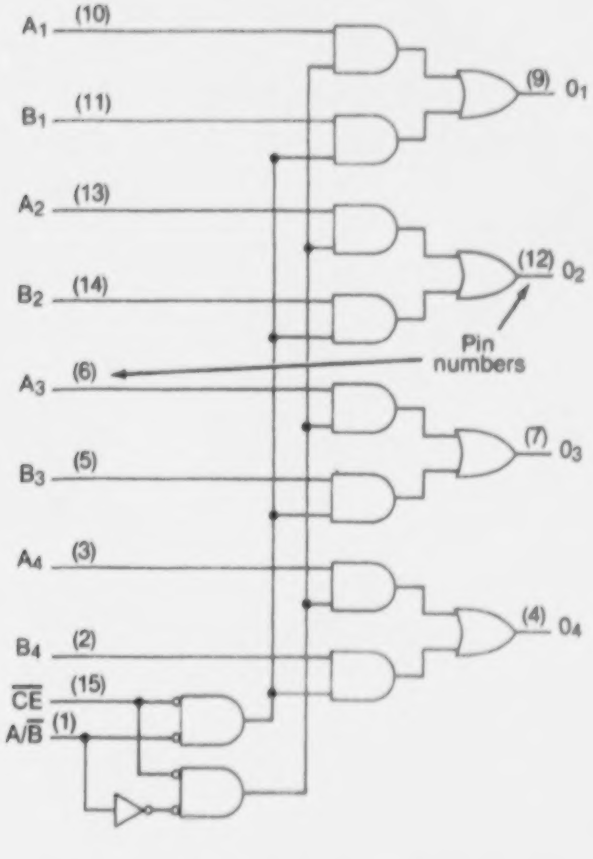


7490 Pinouts

Basic Multiplexers

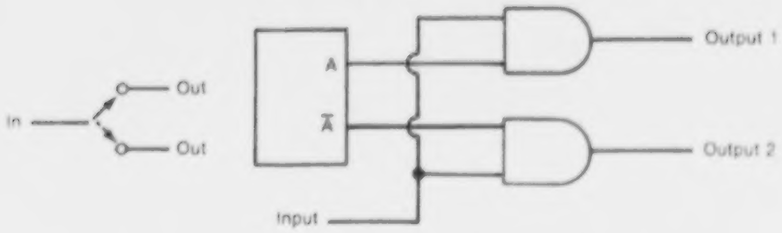


Switch used as a Multiplexer

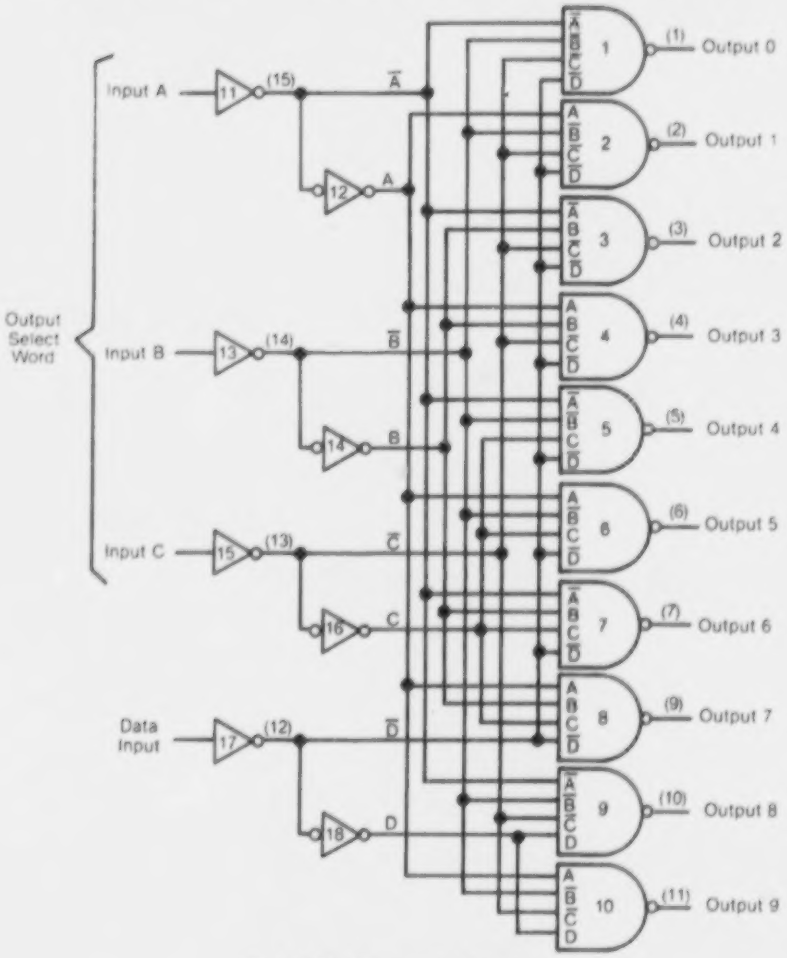


74157 Multiplexer Circuit

Demultiplexers

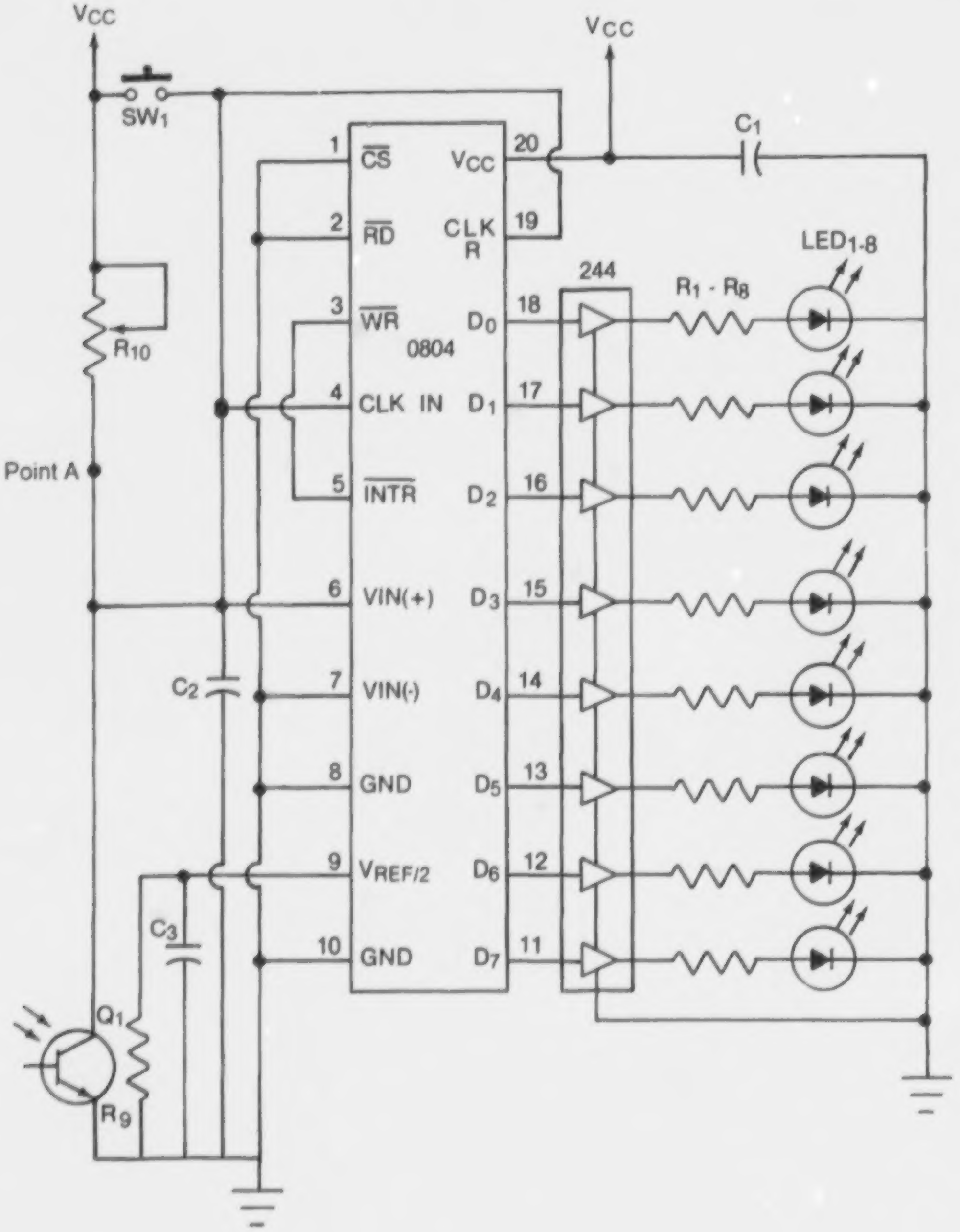


Basic Two - Output Demultiplexer

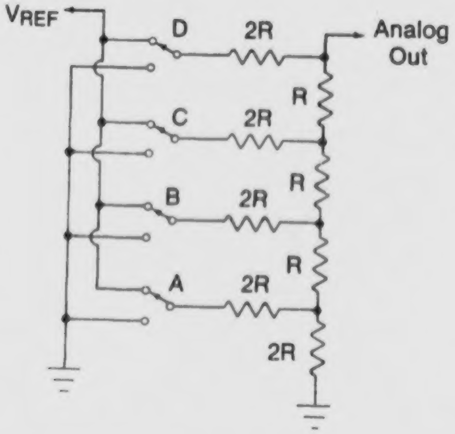


7442 Decoder

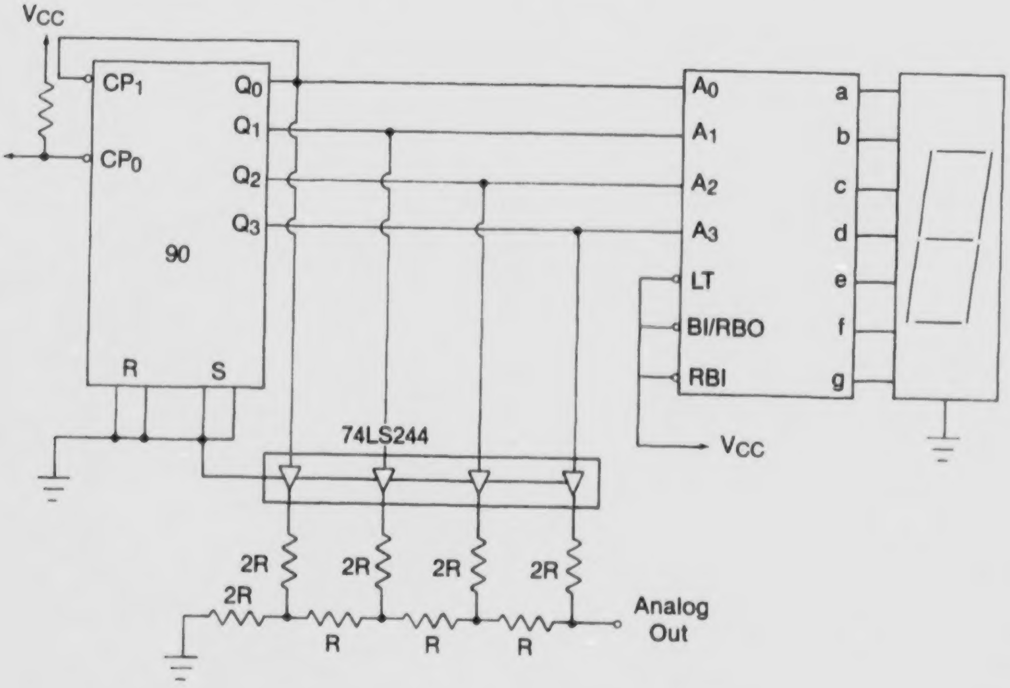
A/D Converter



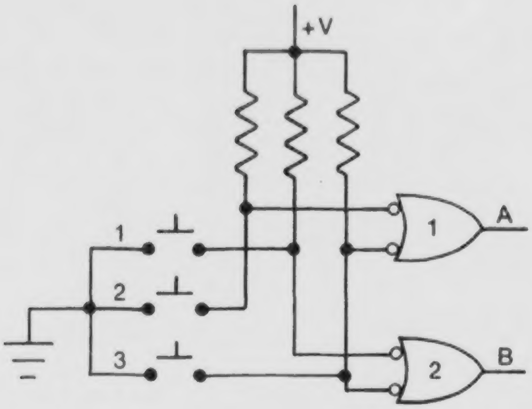
D/A Converter



Basic Ladder D/A Converter

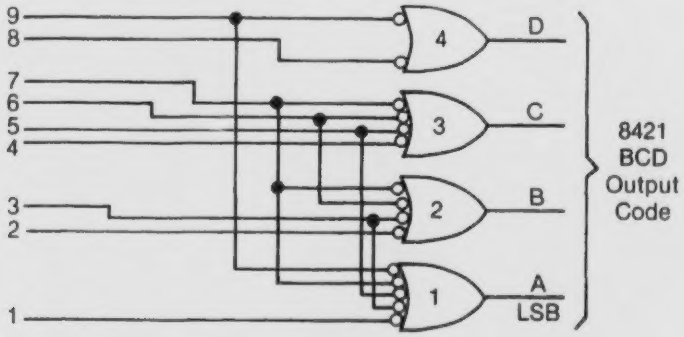


Basic Encoders



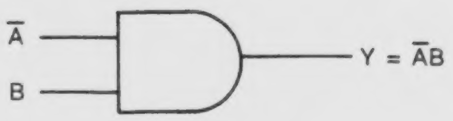
Input	Output	
	A	B
1	0	1
2	1	0
3	1	1

Simple Encoder Circuit

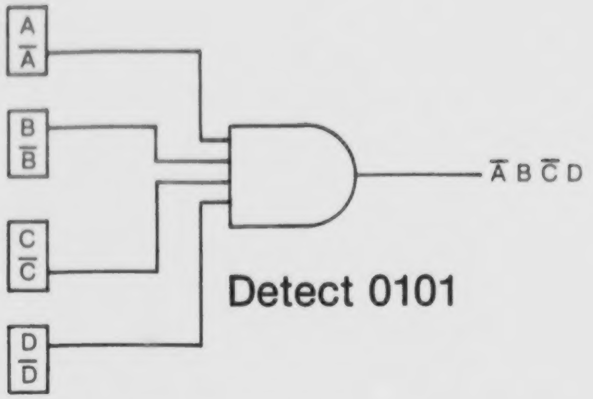


Decimal to BCD Encoder

Basic Decoders



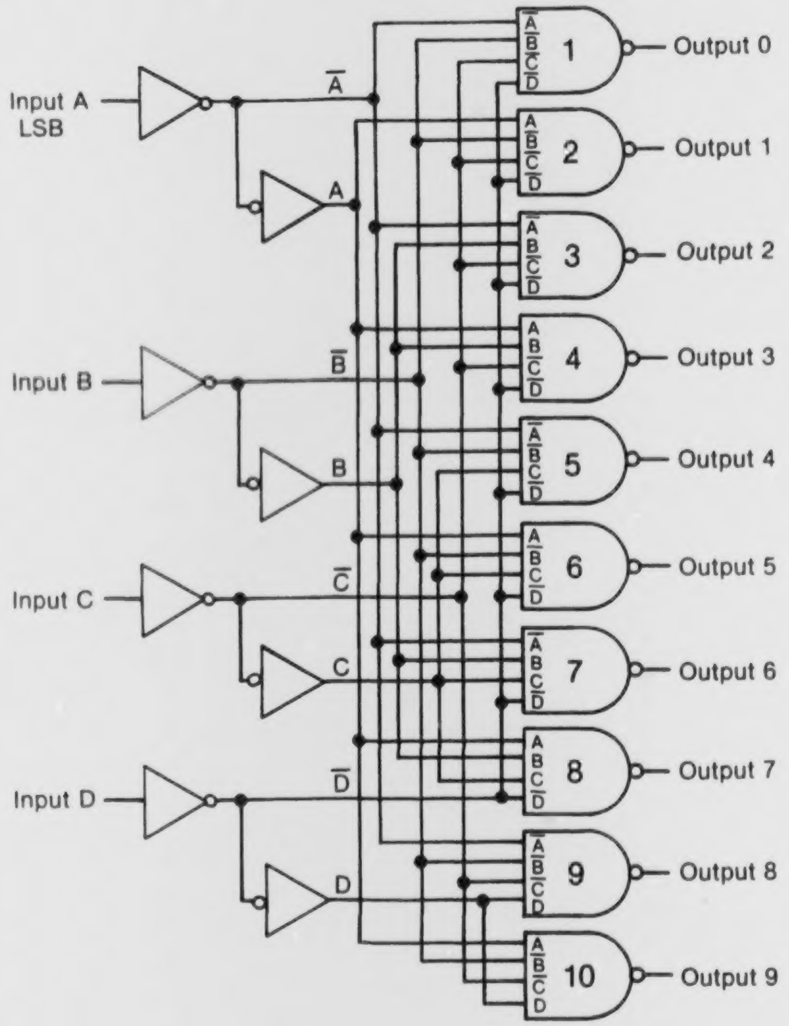
2 - Input AND Gate Decoder
(Detects Number 01)



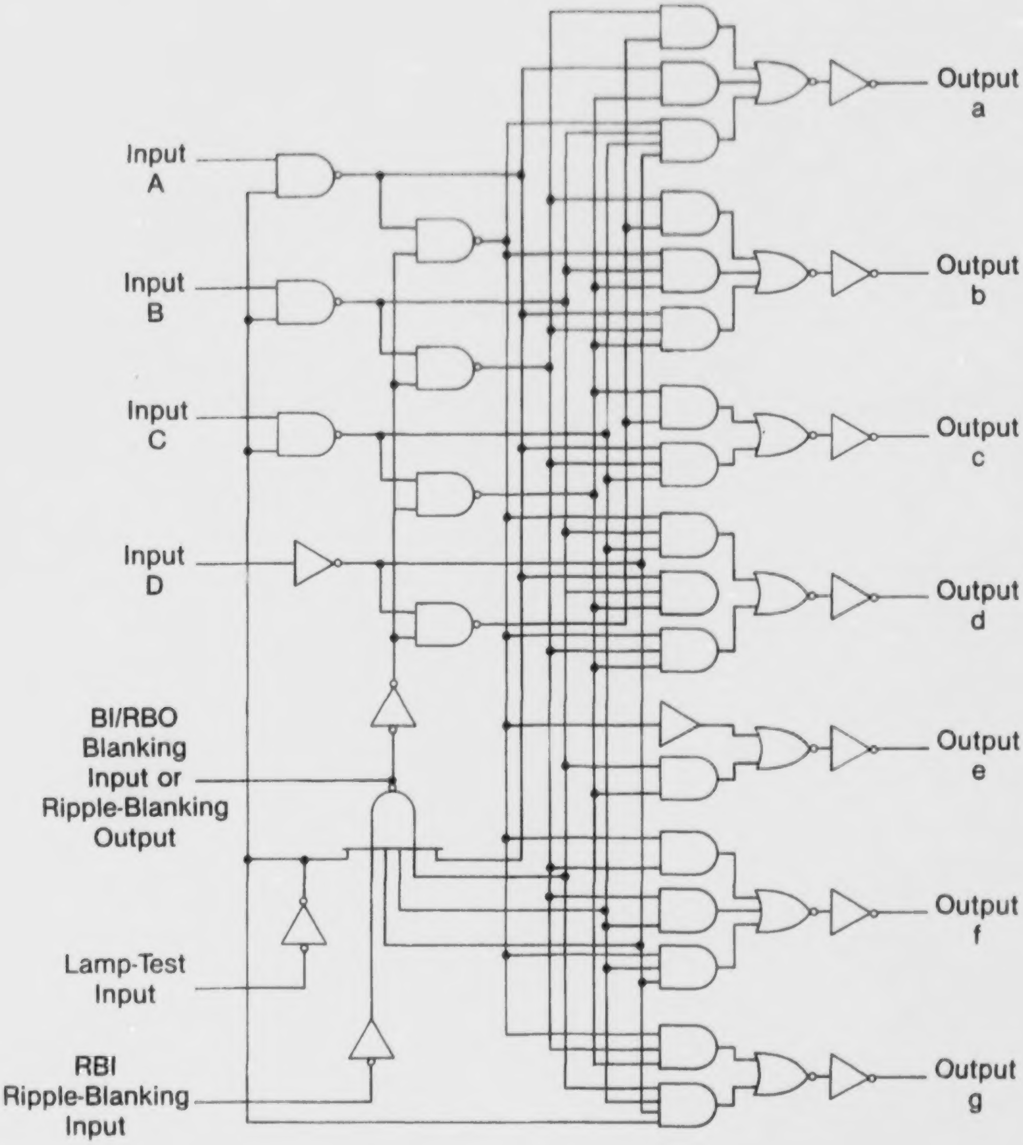
Detect 0101

4 - Input AND Decoder

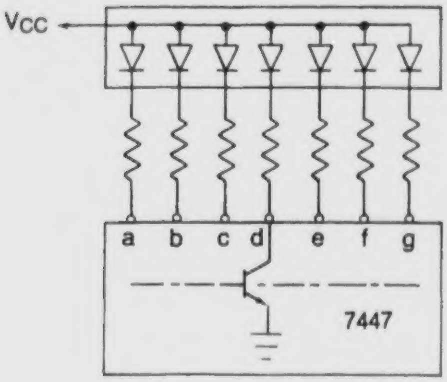
BCD to Decimal Decoder


Input A
LSB
Input B
Input C
Input D
$\overline{A}$
A
$\overline{B}$
B
$\overline{C}$
C
$\overline{D}$
D
$\overline{A}$ $\overline{B}$ $\overline{C}$ $\overline{D}$ 1
A $\overline{B}$ $\overline{C}$ $\overline{D}$ 2
$\overline{A}$ B $\overline{C}$ $\overline{D}$ 3
A B $\overline{C}$ $\overline{D}$ 4
$\overline{A}$ $\overline{B}$ C $\overline{D}$ 5
A $\overline{B}$ C $\overline{D}$ 6
$\overline{A}$ B C $\overline{D}$ 7
A B C $\overline{D}$ 8
$\overline{A}$ $\overline{B}$ $\overline{C}$ D 9
A $\overline{B}$ $\overline{C}$ D 10
Output 0
Output 1
Output 2
Output 3
Output 4
Output 5
Output 6
Output 7
Output 8
Output 9

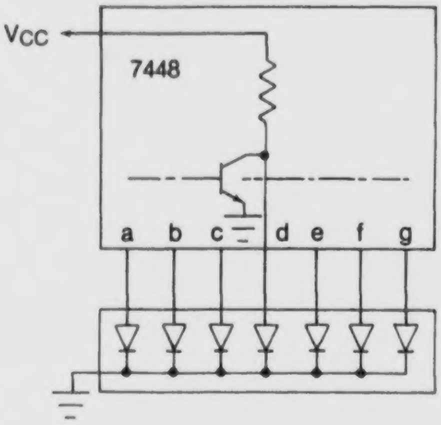
BCD to Seven-Segment Decoder



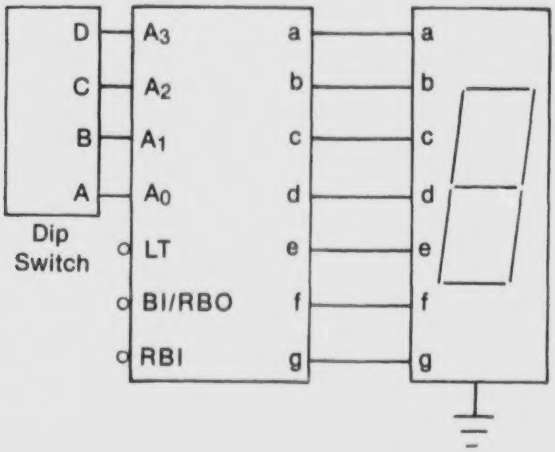
Digital Displays



Common Anode



Common Cathode



BCD to 7-Segment Decoder and Display

Introduction to Microprocessors
Unit 2

Suggested Activities

Instructional Plan

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note the suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain films, videotapes, and other media to supplement instruction of this unit. See ordering information in the suggested resources section.

- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only and should be used with objectives as indicated below.

  TM 1—Microcomputer Interface Blocks (Objective 2)
  TM 2—Simplified Microcomputer Block Diagram (Objective 2)
  TM 3—Microprocessor Block Diagram (Objective 3)
  TM 4—System Architecture (Objective 6)

- Select teacher components (supplement, written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution. The supplement included in this unit is designed for use with the objective indicated below.

  Supplement 1—Report on PC Technology (Various Objectives)

- Prepare classroom. Put up posters and charts and display articles and other references related to the objectives of this unit. Computer manufacturers, software companies, peripheral device distributors, and others distribute posters, ads, and literature about their products that would be useful in supporting this unit. Particularly applicable to this unit are posters of PCs, operating systems, and peripherals. Show types of devices covered in this unit, including types of computers, processor chips, and peripherals.

Suggested Activities

Delivery and Application

Unit Introduction

- Discuss unit and specific objectives.
- Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the job sheets. Review with students the criteria for evaluation of each of these activities.

Teaching Suggestions

The skill areas appearing in bold-face type in the teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of School: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want.* These have been adapted by MAVCC.

- Discuss computers in general and the terms *microcomputer* and *microprocessor* in particular. Assess how much your students know about computers as their knowledge is likely to range from those who have a very high level of computer literacy including configuration and even programming experience to those who have some fear of computers and even some who do not know as much as they think that they do or who have a lot of misinformation about computers. Have the students discuss how they use computers, the systems with which they have worked (including software), the peripherals they have used, what they understand about how computers work, and what they like and do not like about computers. Ask how many hope to be computer technicians or designers. Ask how many expect to have to use computers in their careers as electronics technicians. **(Listening; speaking; career awareness; seeing things with the mind's eye; responsibility; organizational effectiveness)**
- Discuss the operation of computer hardware. Discuss types of microprocessors and coprocessors with which the students may be familiar. Provide the students with information about the problems in introducing the Pentium and other processors. Use microprocessor data sheets to discuss processing speeds, features, built-in capabilities, etc. Discuss and demonstrate the use of sockets and have the class speculate on why sockets have gained widespread use. **(Listening; reading; seeing things in the mind's eye; interpreting and processing information; system interrelationships; technology selection)**

Suggested Activities

- Discuss the flow of data within, into, and out of a computer. Relate data flow to the previous unit on logic gates, shift registers, etc. Relate types of data to previous units on signal processing and conditioning. Discuss electrical characteristics of computer signal and properties of busses and other hardware involved in data transfer, transmission, and storage. Display components and hardware involved and discuss serial and parallel transfers. Discuss communications standards and relate them to particular devices. Include PCMCIA and newer interfaces. **(Listening; reading; reasoning; acquiring, organizing, interpreting, and processing information; science; applying technology; system interrelationships)**

- Discuss computer memory devices. Discuss advantages and limitations of each. Relate types of memory to the various types of devices. Discuss methods of expanding computer memory and demonstrate the installation of SIMMs and similar devices. Demonstrate the operation of CD-ROM and other drives. Discuss other programmable devices, such as PROMS, gate arrays, programmable logic controllers, etc. Discuss drive failures and sector corruption. Discuss compression techniques and other memory-related functions. **(Listening; reading; reasoning; acquiring, organizing, interpreting, and processing information; science; applying technology; system interrelationships)**

- Visit a computer manufacturing facility or component supplier or have a resource person visit your facility to discuss trends in computing. Use Supplement 1 to have students explore developments in computer technology. Have working technicians and engineers discuss how computers have affected the electronics industry and how they use computers in their daily tasks. Demonstrate industry-related applications, such as circuit board layout, circuit simulation and analysis, in-circuit testing, process control, etc. **(Listening; reading; writing; speaking; reasoning; selecting and applying technology; science; seeing things with the mind's eye)**

- Discuss software and peripherals. Discuss software languages and have a software engineer or programmer discuss software development. Demonstrate the use of peripherals, emphasizing the electronic features and functioning of the devices. Have the students speculate on future developments in software and peripherals. For example, discuss developments in displays and graphics drivers and how research in these are likely to be further fueled by video-game companies, automotive manufacturers, test equipment companies, and others who are looking for ways to clearly and attractively present real-time dynamic information. Discuss issues like sunlight readability, pixel defects, color saturation, viewing angle, and similar factors related to the operator's ability to extract useful information from the display and the constraints of heat, weight, manufacturability, cold, etc. Discuss high-density television and flat-panel technology, as well as active and passive matrix designs. **(Listening; reasoning; applying technology; seeing things with the mind's eye; system interrelationships; materials and facilities)**

Evaluation

- Discuss with students the use of the Unit Evaluation Form. Explain the rating scale that will be used for student evaluation.
- Copy written test and give to students as pretest. Record pretest score on the Unit Evaluation Form.
- Evaluate job sheets. See the evaluation criteria listed at the top of each job sheet.
- Give and evaluate written test.
- Compile written-test and job sheet scores on the Unit Evaluation Form. Include any additional assignments.
- Measure competency gains by comparing written pretest scores with posttest scores.
- Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- Reteach and retest as required.

Instructions for Evaluating Student Performance

- When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

1 — Skilled—Can perform job with no additional training.
2 — Moderately skilled—Has performed job during training program; limited additional training may be required.
3 — Limited skill—Has performed job during training program; additional training is required to develop skill.
4 — Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Suggested Resources

Resources Used in Developing This Unit

- *Basic Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Communications Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1988.
- Davidson, Homer L. *Electronic Troubleshooting and Repair Handbook.* New York: McGraw-Hill, 1995.
- *General Electronics Technician.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, Inc., 1975.
- McMenamin, J. Michael. *Applied Electronic Devices and Analog ICs.* Albany, New York: Delmar Publishing, Inc., 1995.
- Reis, Ronald A. *Electronic Project Design and Fabrication.* 3rd edition. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1995.
- Roehrig, Guido and Ulrich Schueller. *Upgrading and Maintaining Your PC.* Grand Rapids, Michigan: Abacus, 1991.

- Schuler, Charles A. *Electronics Principles and Applications.* 4th edition. New York: Glencoe Division, Macmillan/McGraw-Hill School Publishing Company, 1994.
- Simpson, Colin D. *Principles of Electronics.* Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1996.
- Sinclair, Ian. *Build Your Own PC.* Oxford, England: Butterworth-Heinemann Ltd., 1994.
- Villanucci, Robert S., Alexander W. Avtgis, and William F. Megow. *Electronics Techniques: Shop Practices and Construction.* 5th Edition. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1996.

Supplemental Resources

Print Media

- "Reinventing the PC." *Discover Magazine*, September 1995. This is a good article on possible paths that future PCs could take. It is well suited for students who are not computer whizzes. For the latter class of students you may want to check out magazines more oriented to computer technology, such as *PC*, *Byte*, etc.
- Data sheets for applicable semiconductor devices. Available from manufacturers and in handbooks.
- Schematics for circuits discussed in conjunction with this unit. Available from equipment manufacturers.

Non-print Media

- *How to Write a Program in BASIC.* An overview of the programming process, using BASIC as the programming language. Available from: Guidance Associates; 90 S. Bedford Rd.; Mt. Kisco, NY 10549; 800-431-1242.
- *Introduction to Computers.* A general explanation of how computers work. Available from: Increase Video; 6914 Canby Ave., Suite 110; Reseda, CA 91335.
- *Introduction to Computer CPUs.* A good overview of CPUs, but it will prove a disappointment if your students expect to hear about the latest devices. Available from: Library Filmstrip Center; 608 E. Locust St.; Bloomington, IL 61701.

Suggested Activities

- *Microcomputer Circuits Explained.* An overview of the construction and operation of computer circuitry. Available from: Bergwall Productions, Inc.; P.O. Box 238; Garden City, NY 11530-0238; 800-645-3565.
- *Microcomputer Device Modules.* A series of six programs covering various sections of a microcomputer and peripherals, including memory, I/O devices, printers, input devices, data storage, etc. Available from: NUS Training Corporation; 910 Clopper Rd.; Gaithersburg, MD 20878-1399; 800-848-1717.
- *Microprocessor Bus Structures.* This is one program in a series of modules covering all aspects of microprocessor operation and interfaces. Other programs in the 11-part series include those dealing with instructions, interrupts, addresses, and other signals and operations. Available from: NUS Training Corporation; 910 Clopper Rd.; Gaithersburg, MD 20878-1399; 800-848-1717.
- *Semiconductor Memories--Dynamic PROM Memories.* Covers PROM devices, their roles in circuits, and how they are loaded and overwritten. Available from: Heathkit/Zenith; Educational Systems Division; Veritechnology Electronics Corporation; P.O. Box 167; St. Joseph, MI 49085

Introduction to Microprocessors
Unit 2

Answers to Written Test

1. a. 7
   b. 3
   c. 14
   d. 9
   e. 10
   f. 8
   g. 1
   h. 2
   i. 15
   j. 11
   k. 4
   l. 13
   m. 5
   n. 12
   o. 6

2. a. Microprocessor
   b. Storage
   c. Drives
   d. System bus
   e. Input
   f. Output
   g. Expansion
   h. Input
   i. Bidirectional
   j. Output

3. a. 4
   b. 5
   c. 1
   d. 3
   e. 2

4. a. Control section—Receives instructions from the data bus, decodes them, and processes clock timing and interrupt signals
   b. Register section—Carries out operations, calculations, memory retrieval, and similar functions

5. a. 1
   b. 2
   c. 5
   d. 4
   e. 6
   f. 3

6. a. Address word—Originates in the microprocessor and flows to the remaining parts of the system
   b. Data word—Originates outside of the microprocessor, flows into the microprocessor, and out to the system
   c. Control information—Flows in and out of the microprocessor

7. a. Instruction
   b. Register
   c. Microprocessor

8. a. 5
   b. 3
   c. 2
   d. 1
   e. 4
   f. 6

Answers to Written Test

9. a. Silicon pathway
    b. Printed circuit pathway
    c. Wire conductor

10. a. Standard
    b. Expansion cards

11. a. Either a multiconductor cable or PCB
    b. Parallel
    c. Bi-directional
    d. Address

12. a. Multiconductor
    b. Microprocessor
    c. Location

13. a. Functions
    b. Direction
    c. Less
    d. Interrupt

14. a. Microprocessor
    b. Two
    c. Low
    d. Does not
    e. Clock
    f. Inoperative
    g. Interrupt

15. a. An interrupt is a signal from a device that is requesting service by the microprocessor.
    b. An interrupt will cause a microprocessor to stop what it is doing and perform some other operation for which it has been programmed.
    c. Interrupts permit external asynchronous input into the microprocessor so that it may be used for multiple purposes.

16. a. Counter
    b. Address
    c. Memory
    d. Data
    e. Instruction
    f. Decoder
    g. CPU
    h. Registers

17. a. A
    b. M
    c. M
    d. A
    e. A
    f. M
    g. A
    h. M
    i. A
    j. M
    k. M

Answers to Written Test

18. a. SCSI parallel
    b. Centronics parallel
    c. Serial

19. a. To control the allocation and usage of hardware, such as memory, the CPU, disk space, and peripherals
    b. To provide a standard interface for software applications, such as word-processing and spreadsheet programs

20. a. 10
    b. 6
    c. 7
    d. 1
    e. 2
    f. 8
    g. 4
    h. 5
    i. 9
    j. 3

Introduction to Microprocessors
Unit 2

Written Test

Name ________________________ Date __________ Score __________

1. Match terms associated with microprocessors to their correct definitions. Write the corresponding numbers on the blanks provided.

______a. Point of connection between two devices or the hardware or software that provides that interconnection

______b. Electronic device that, upon the receipt of instructions, can perform calculations on numerical information and can store and correlate other forms of information, such as words, images, and digitized sound

______c. Communications exchange accomplished with software

______d. Any of various systems for representing data, instructions, and operational information for use by a computer

______e. Area of computer or other programmable device in which information can be stored either temporarily or until deleted or changed

______f. Signal sent by a computer-internal device requesting service from the microprocessor

______g. String of symbols such as binary bits used to indicate the memory location of data or an input/output device

______h. Conductive path within a computer over which instructions and data are transmitted

______i. Electronically recorded programs stored in such a manner that they can be inserted into or removed from a computer

1. Address word
2. Bus
3. Computer
4. Data word
5. Firmware
6. Hardware
7. Interface
8. Interrupt
9. Language
10. Memory
11. Operating system
12. Peripheral
13. Program
14. Protocol
15. Software

Written Test

______j. Format for the master control program of a computer that is permanently stored in memory and that interprets commands so that devices and programs can interface

______k. String of symbols such as binary bits used to represent information other than instructions in computer operations

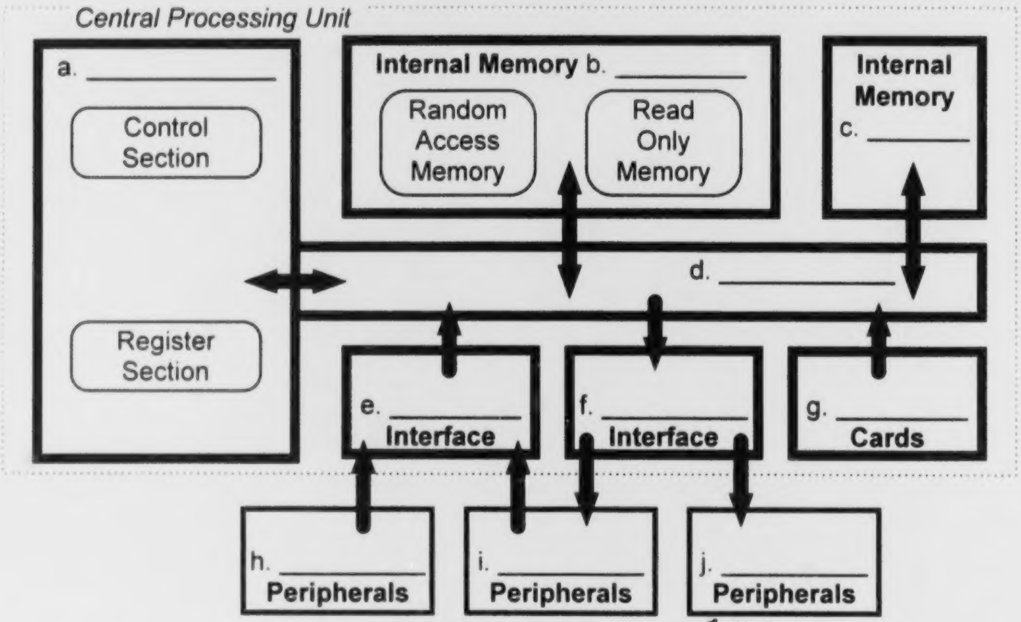
______l. Detailed set of instructions that describe operations to be performed by a computer to accomplish specific tasks

______m. Hardware that contains embedded software

______n. Any device external to a computer that is electrically connected to the computer and which provides information to the computer or processes information from the computer

______o. The physical components of a computer system

2. Label the parts of a computer block diagram.



Written Test

3. Match the sections of a computer to their correct descriptions. Write the corresponding numbers on the blanks provided.

   ______a. Contains random access memory (RAM) and read-only memory (ROM), as well as magnetic memory for temporary or permanent storage of information

   ______b. Internal devices where stored information is manipulated in data groups

   ______c. System wires or printed circuits used to connect the CPU to the remainder of the system

   ______d. Contains circuitry to provide interfaces to peripheral devices and networks

   ______e. Contains the arithmetic logic unit (ALU), control circuitry, some registers, and a program/address counter

   1. Busses
   2. Central processing unit
   3. Input/output section
   4. Memory section
   5. Registers

4. State the purpose of the two major sections of the central processing unit.

   a. Control section—____

   ____

   b. Register section—____

   ____

5. Match functional areas of the CPU register section to their correct descriptions. Write the corresponding numbers on the blanks provided.

   ______a. Stores quantities to be operated on by the ALU and receives the results of the arithmetic operation performed by the ALU

   ______b. Performs calculations, sends information to the accumulator, and initiates the output to the flag register

   ______c. Controls the step-by-step progress of operations as the CPU executes a program

   1. Accumulator
   2. Arithmetic logic unit
   3. Flag register
   4. Index register
   5. Program counter
   6. Stack pointer

______d. Increments and decrements through the memory contents to help accomplish a repetitive task

______e. Keeps track of where information is when memory stacking occurs and points the programmer to data storage locations

______f. Contains bits of data that indicate the status of the microprocessor at the end of the last instruction that was executed

6. Describe the three ways in which information flows through a microprocessor. For each type of information listed below, state how that type of information flows through a microprocessor.

   a. Address word—____

   ____

   b. Data word—____

   ____

   c. Control information—____

   ____

7. Complete statements about the flow of information through a microprocessor. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

   a. To start information flow, an ______________ word is sent to the microprocessor via the data line in the data bus.

   b. The information contained in the instruction is a binary word from the data bus and is deposited in the instruction (RAM, register).

   c. The received instruction word will be latched into the instruction decode section of the (microprocessor, system bus), where it is decoded.

Written Test

8. Match types of memory devices to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Nonvolatile data stored in an IC, compact disc, or computer hard drive; usually includes programming to control basic operations and such decoding functions as reading the keyboard and controlling video information for display

______b. Nonvolatile data stored in an IC or circuit that can be erased with ultraviolet light and reprogrammed

______c. Nonvolatile data stored in an IC or circuit that can be erased and reprogrammed electronically

______d. Volatile data storage that retains data for one or two milliseconds so that it must be continually refreshed if the data is to be retained

______e. Volatile data storage that is easily written, read, and rewritten by the operator or computer

______f. Volatile data storage that retains its contents until altered or power is removed

1. Dynamic random access memory
2. Electronically erasable programmable read-only memory
3. Erasable programmable read-only memory
4. Random access memory
5. Read-only memory
6. Static random access memory

9. List types of bus construction.

a. ____

b. ____

c. ____

10. Complete statements about the system bus. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Is generally designed to comply with a bus interface ______________.

b. Provides interface for adding (expansion cards, monitors) and other devices to change or enhance the computer's capabilities.

Written Test

11. Complete statements about data busses. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. Is generally a (multiconductor cable, PCB, either a multiconductor cable or PCB) pathway.

    b. Carries information in specific sized word groups in (serial, parallel) to and from the microprocessor.

    c. The word groups are synchronized by the system clock with bus operation being (uni-directional, bi-directional).

    d. The word groups may contain instructions, data, or _______________ information.

12. Complete statements about address busses. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. Is generally a (single-strand, multiconductor) cable or PCB pathway.

    b. Carries addresses generated by the (system bus, microprocessor) to designated devices.

    c. Information carried indicates _______________ in RAM, ROM, or I/O device to which the data is being sent or from which the microprocessor may retrieve the information.

13. Complete statements about control busses. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. May provide specialized (addresses, functions) specific to the system.

    b. Controls timing and _______________ of information flow.

    c. Signals tend to be (more, less) synchronized than on other busses.

    d. Usually carries clock pulses, read/write signals, and (interrupt, synchronization) signals.

Written Test

14. Complete statements regarding clock timing in a microprocessor. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. Timing may be an internal function of the (microprocessor, memory section) or provided through a separate clock circuit.

    b. The clock pulse is usually a (one, two, one or two) -phase, nonoverlapping waveform created by starting two signals of the same frequency at slightly different times.

    c. When one waveform is high, the other is ______________, allowing the signals to be identified as phase one (high) and phase two (low).

    d. The clock provides timing signals to all parts of the system and (does, does not) need to be addressed.

    e. The CPU controls the system busses, and the ______________ controls timing to all of the system.

    f. If the clock fails, the system is (inoperative, still operative).

    g. A high-speed timing cycle may be manipulated by an (interrupt, overwrite) signal from the computer operator or from an external device.

15. Explain the purpose and operation of an interrupt.

    a. What an interrupt is—____

    ____

    b. How it works—____

    ____

    c. What it permits—____

    ____

Written Test

16 Complete statements about computer operation. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Before a program may be executed, the program ______________ must be set to a memory location that begins the program.

b. The CPU places the contents of the program counter on the (address, data, system) bus.

c. The program counter proceeds to the next sequential (clock, memory) location, where it stops until it receives instructions from the CPU decoder section.

d. The address bus selects the contents of the memory specified and places the instruction that it finds onto the (address, data, system) bus.

e. The data bus carries the data to the (flag, instruction) register of the CPU.

f. The CPU (decoder, ALU) sets the appropriate registers in response to the instruction.

g. If additional data is required, the (operator, CPU) will query the program counter for the required address on the system address bus to retrieve data from other memory addresses.

h. Once all the data has been received and the ______________ have been set, the CPU will execute the program.

17. Distinguish between the use and functioning of machine and assembler languages. Write an "A" beside each statement below that applies to the use and functioning of assembler language and an "M" beside each that applies to machine language.

______a. Uses mnemonics, which are generally three- or four-letter codes that may be abbreviations for the operations they represent.

______b. Requires the computer operator to specify memory addresses in the computer and machine codes that are understood by the computer control section.

______c. Language in which most system troubleshooting routines are written.

______d. Addressing is done with labels rather than specific addresses.

______e. No allowance is necessary for specific microprocessors while writing the program.

______f. Requires the use of codes and addressing modes that are specifically suited for the computer's microprocessor.

Written Test

______g. Once written, the program must be processed through an assembler to convert the program to a format that the computer will understand.

______h. Usually requires longer to create a program.

______i. Generally is easier and faster for the programmer.

______j. Requires the use of data for operations in a suitable code, such as binary or hexadecimal.

______k. Completed programs execute faster.

18. Distinguish among characteristics of various communications standards. For each set of characteristics listed below, identify those characteristics as applying to one of the following communications standards:

- Serial
- Centronics parallel
- SCSI parallel

a. ______________________________

- Uses hardware standard known as Small Computer System Interface.
- Supports up to eight devices.
- Has no formal driver standards.

b. ______________________________

- Industry standard is Centronics for parallel communications.
- Commonly used to connect printers to computers.
- Provides electrical parameters.
- Provides dimensions and pin assignments for a standard interface.

c. ______________________________

- Communications standard RS-232 as defined by the Electronics Industry Association is the accepted guideline for serial communications.
- Provides electrical parameters.

Written Test

- Provides dimensions and pin assignments for a standard interface.
- Allows for prescribed exchange of predetermined signals upon initial connection between two devices (*handshaking*).
- Defines high- and low-bit signals used to mark the beginning and end of a transmitted word.

19. State the two major purposes of a computer operating system.

a. ______________________________

____

b. ______________________________

____

20. Match types of computer peripherals to their correct descriptions. Write the corresponding numbers on the blanks provided.

_____a. Input device that is generally laid over the monitor screen to allow the operator to input commands by means of touching the screen

_____b. Output device that provides a visual representation of computer status and operations

_____c. Input device that provides the operator with a means of selecting displayed choices of operations by moving a pointer

_____d. Input device that provides the operator limited input options for specialized programs such as interactive games

_____e. Input device that provides the operator with a means of transmitting symbols to the CPU using keys as on a calculator or typewriter

_____f. Output device that can convert data stored in the computer to symbols printed on paper

1. Joystick
2. Keyboard/keypad
3. Light pen
4. Memory drives
5. Modem
6. Monitor
7. Mouse
8. Printer
9. Scanner
10. Touchscreen

Written Test

______g. Input/output devices that can be used to supplement the computer memory, provide additional types of storage, or input data

______h. Input/output device to allow the computer to interface with telephone lines

______i. Input device that converts printed images into digital signals that can be processed by the computer

______j. Input device for use on monitor screens that are sensitive to signals emitted by the pen

***Permission to duplicate this test is granted.**

Introduction to Microprocessors
Unit 2

Unit Evaluation Form

Student Name ______________________________ Unit Rating ____________

Job Sheet Ratings

Job Sheet 1—Write and Run a Machine Language Driver Program to Check Read/Write Memory Location Rating _____

Comments: ____

____

Job Sheet 2—Use a Digital Voltmeter to Test Supply Voltages on a Microcomputer System Bus Rating _____

Comments: ____

____

Job Sheet 3—Use an Oscilloscope to Check a Computer Clock System Rating _____

Comments: ____

____

Job Sheet 4—Set Up and Configure a Personal Computer Rating _____

Comments: ____

____

Job Sheet 5—Troubleshoot Microprocessor Circuits Rating _____

Comments: ____

____

Unit Evaluation Form

Written-Test Scores

Pretest _______ Posttest _______ Other _______

Other ____

____

Teacher Signature ______________________ Date ____________

Student Signature ______________________ Date ____________

***Permission to duplicate this form is granted.**

Introduction to Microprocessors
Unit 2

Supplement 1—Report on PC Technology

Introduction Computer and software technology is developing at an amazing rate, and no print material on the subject can hope to remain current for long. At the time of this writing (late 1996), the new models of PCs offer the Intel 586 processor at 200 MHz, come with 3.8 GB hard drives, 64-bit graphics capabilities, and built-in surge protectors, CD-ROMs, fax/answering machine/modem cards, graphics accelerators, and many more features that were not available or were only available as add-ons just a few months ago. Compaq has just released a model with a flat-panel monitor attached to the CPU case, making it a hybrid between a laptop and workstation unit.

Similarly, new software is being released (or promised) on a daily basis. Peripherals are offering more features, better output, and (usually) lower costs than ever before. Ink jet and bubble jet printer resolution rivals what was available only in high-end laser printers just a few years ago and provide color printing as well.

Your students will be aware of some of these advances, but some may not even remember when there were no PCs. A couple of historical perspectives may help them understand the advances made in the 50-plus years since the invention of the computer:

- The first electronic, general purpose computer became operational in 1945 at the University of Pennsylvania. It was called ENIAC for Electronic Numerical Integrator and Computer. It weighed 30 tons, required 1800 square feet of floor space, and contained 17,000 vacuum tubes. Six technicians were kept busy replacing the vacuum tubes as they blew out. In order to change ENIAC's program, the computer had to be rewired in order to redirect instructions.

- In 1949, an article in *Popular Science* magazine astounded the world by predicting that computers would one day weigh less than one-and-one-half tons and fit into an average size room.

- In the mid-70s, Altair introduced a $400 kit with which one could build a personal computer. It provided limited programming and data entry through the positioning of toggle switches. It had no keyboard, external memory, or printer.

- In the early 1980s, the chief executive officer of Digital Equipment Company stated that "the personal computer will fall flat on its face."

Supplement 1

- To date, nearly 150 million PCs have been sold in the United States alone.

Your class is likely to have students with a wide range of computer knowledge. Some will be fairly unfamiliar with computers and how they operate. Others are likely to treat computers the way their fathers (or grandfathers) treated cars—powerful plaything-tools to be customized and sup'ed up. Customize this supplement to allow both types of students and all those in between to get the most out of exploring PC technology.

Directions Copy the form on the next page for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in PC technology. Assign each student an appropriate hardware or software system or allow the students to choose items of their own interest. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: This supplement lends itself for flexible use in the classroom. Consider the following applications and alternatives:

- Use the supplement only for students who are ahead of the rest of the class to expand their studies.
- Use hardware and software that relate to the objectives of this unit. Have some students do CPUs, some memory devices, some peripherals, some software, etc. Have the students share their reports as the class is studying that particular objective. This not only makes the exercise more relevant but also keeps the reports from being bunched up in a few class periods.
- Tailor the complexity of the requirements to the student's abilities. Have advanced students report on more complex or specialized issues, while other students report on the more common applications.
- Use variations in the report format, allowing the students some opportunities for creativity. These variations should be appropriate for the abilities and interests of your students. For example, you may have the students create posters about their devices or software. If you have a computer network available, you can create an "internet" with the students creating "home pages" that other students can access.
- Have students use the subject of their report component in a practical application. For example, have students install peripherals on which they report or load software as part of Job Sheet 4.

Supplement 1

Report on PC Technology

Student Name ______________________________ Date ______________

Name/Number of Device ____

Manufacturer ______________________________________ ___________

General uses of device_____ ____________________________________

____

Available packages (materials and types) _________________________

____

Hardware requirements

Type and speed of processor_________________________________

Memory requirements (ROM and RAM)__________________________

Interface requirements_______________________________________

Special circuit card requirements (sound, video, modem, etc.)______________

____

Software requirements

Operating system____

Other software____

Your evaluation of product

____

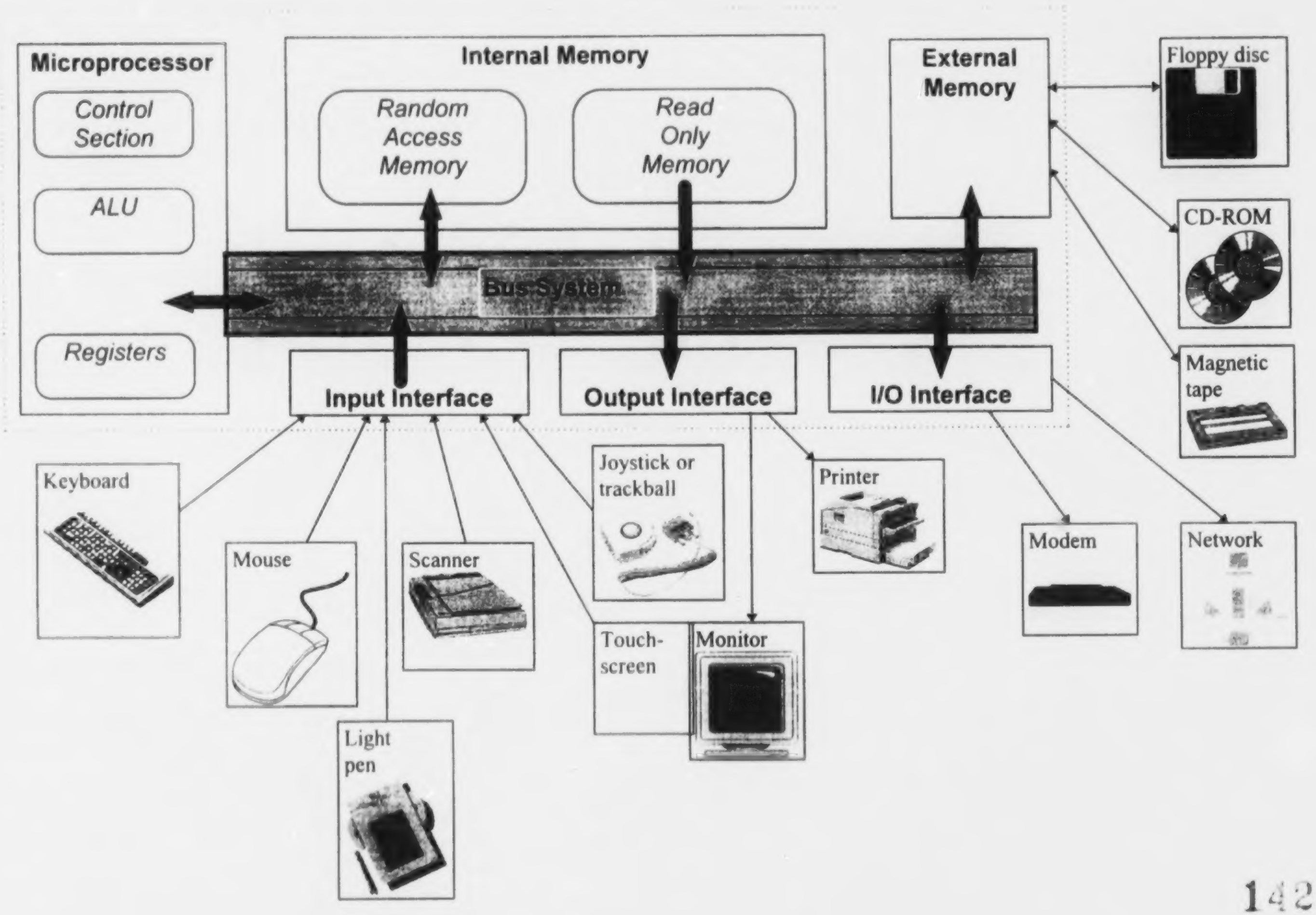
____

____

____

*Permission to duplicate this form is granted.

Microcomputer Interface Blocks

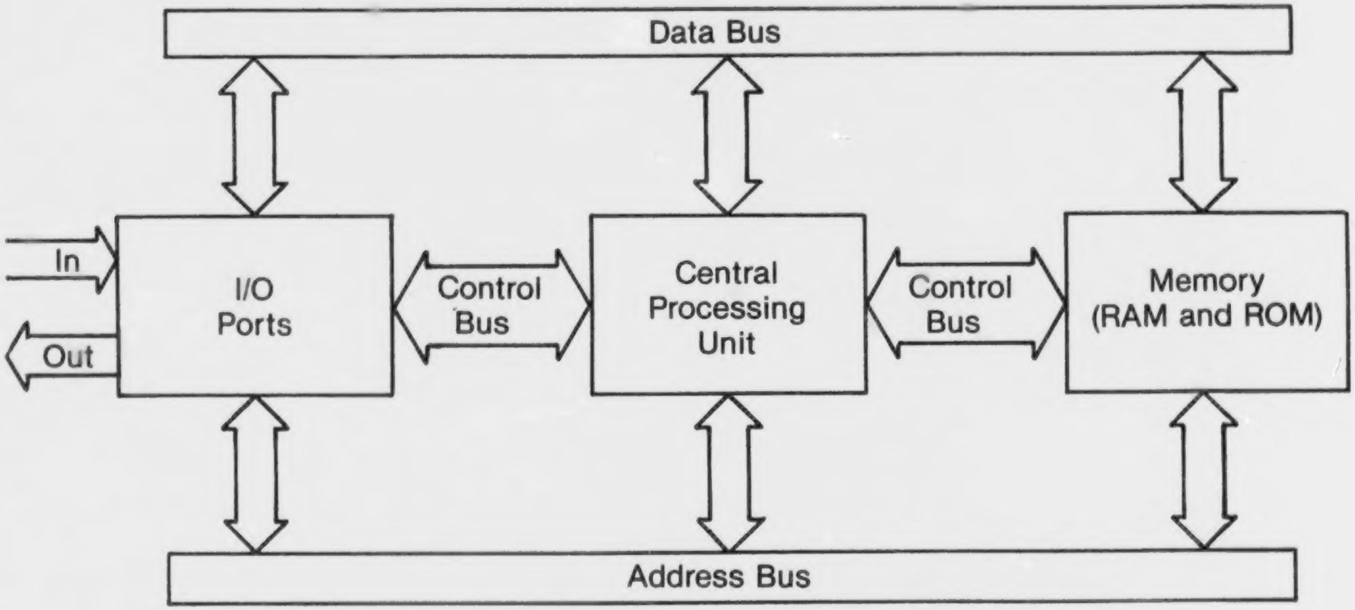


General Electronics Technician: Digital Electronics and Introduction to Microprocessors, Unit 2
Teacher Page 31

TM 1

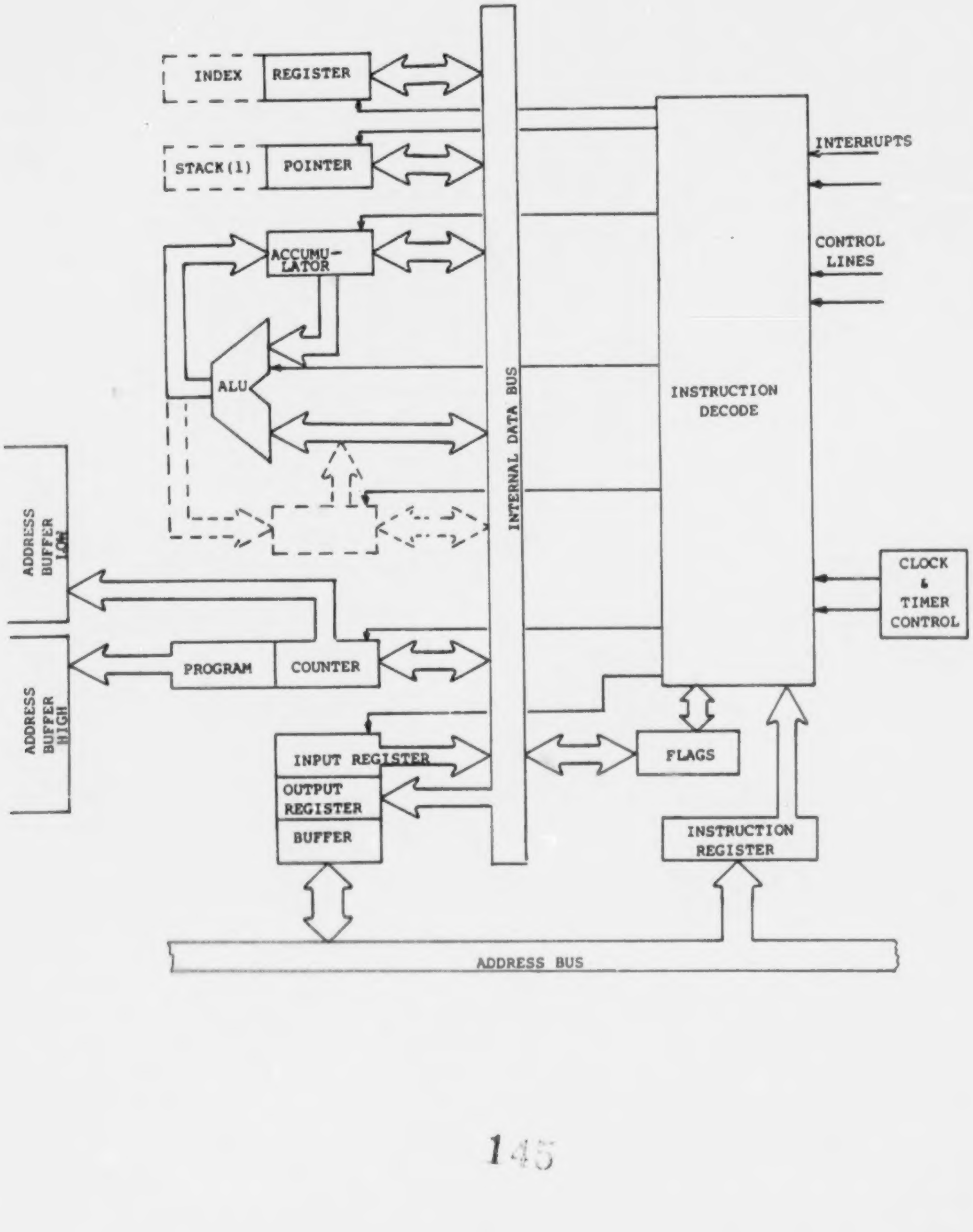
BEST COPY AVAILABLE

Simplified Microcomputer Block Diagram



TM 2

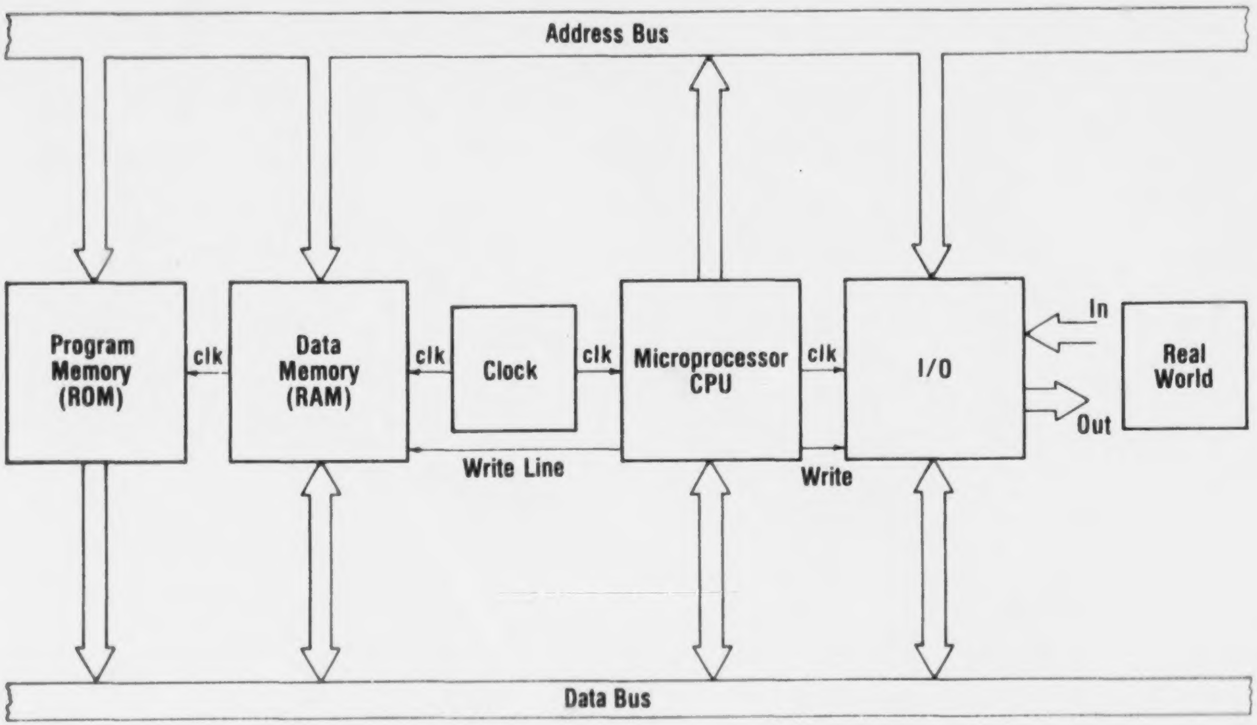
Microprocessor Block Diagram



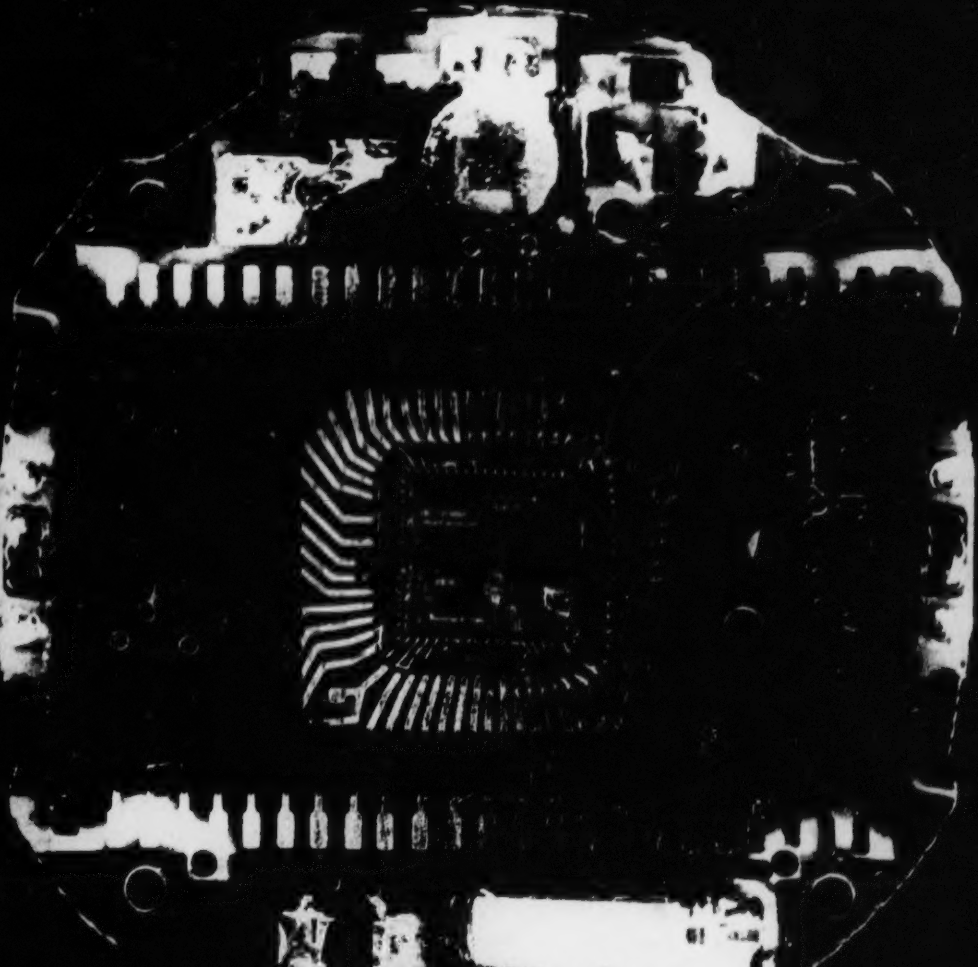
145

TM 3

System Architecture



General Electronics Technician: Digital Electronics and Introduction to Microprocessors



Student Edition

MAVCC

BEST COPY AVAILABLE

General Electronics Technician:

Digital Electronics and Introduction to Microprocessors

Student Edition

Written by
Robert Hilley, Technical Writer

Project coordinated by
Jane Huston, Curriculum Coordinator
Multistate Academic and Vocational Curriculum Consortium, Inc.

Project developed by
The Multistate Academic and Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, Oklahoma 74074-4364

©1997

The Multistate Academic and Vocational Curriculum Consortium (MAVCC) does not discriminate on the basis of race, creed, color, national origin, sex, age, religion, veteran status, or qualified handicap.

General Electronics Technician:

Digital Electronics
and
Introduction to Microprocessors

Student Edition

Table of Contents

DM

Unit 1: Logic Devices and Circuits 1

Unit 2: Introduction to Microprocessors 107

Logic Devices and Circuits
Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss logic devices and circuits and be able to build and test logic circuits. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms associated with logic devices and circuits to their correct definitions.
2. Complete statements about how signals represent information.
3. Match numbering systems used with logic circuits to their correct descriptions.
4. Match types of logic gates to their correct descriptions.
5. Label logic gate symbols.
6. Distinguish types of multivibrator circuits by their characteristics.
7. Complete a diagram of a set-reset flip-flop.
8. Complete a diagram of a J-K flip-flop.
9. Match types of counters to their correct descriptions.
10. Complete a diagram of a shift register.
11. List functions that can be performed by shift registers.
12. Complete statements regarding the operation of timing circuits.
13. List functions of clock and timing circuits.
14. Select from a list functions of arithmetic-logic circuits.
15. Complete statements about the operation of multiplexer circuits.
16. Match types of analog/digital conversion circuits to their correct descriptions.

Objective Sheet

17. Describe the operation of encoder/decoder circuits.
18. Complete statements regarding noise problems.
19. Distinguish common IC logic families by their characteristics.
20. Match characteristics of electronic displays to their correct descriptions.
21. Match types of displays to their correct descriptions.
22. Convert octal numbers to decimal numbers. (Assignment Sheet 1)
23. Convert decimal numbers to octal numbers. (Assignment Sheet 2)
24. Convert decimal numbers to binary numbers. (Assignment Sheet 3)
25. Convert binary numbers to base ten numbers. (Assignment Sheet 4)
26. Use the double-dabble method to convert binary numbers to decimal numbers. (Assignment Sheet 5)
27. Convert binary numbers to octal numbers. (Assignment Sheet 6)
28. Convert octal numbers to binary numbers. (Assignment Sheet 7)
29. Convert binary numbers to hexadecimal numbers. (Assignment Sheet 8)
30. Convert hexadecimal numbers to binary numbers. (Assignment Sheet 9)
31. Complete logic tables. (Assignment Sheet 10)
32. Apply Boolean operations to minimizing logic circuits. (Assignment Sheet 11)
33. Construct and test an "AND" gate circuit. (Job Sheet 1)
34. Construct and test an "OR" gate circuit. (Job Sheet 2)
35. Construct and test a "NAND" gate circuit. (Job Sheet 3)
36. Construct and test a "NOR" gate circuit. (Job Sheet 4)
37. Construct and test an "exclusive-OR" gate circuit. (Job Sheet 5)
38. Construct and test a four-bit shift register. (Job Sheet 6)
39. Construct and test a flip-flop circuit. (Job Sheet 7)
40. Construct and test a J-K counter circuit. (Job Sheet 8)

Objective Sheet

41. Construct and test an A/D converter. (Job Sheet 9)
42. Construct and test a D/A converter. (Job Sheet 10)
43. Construct and test a BCD to seven-segment decoder. (Job Sheet 11)
44. Troubleshoot logic circuits. (Job Sheet 12)

Logic Devices and Circuits
Unit 1

Information Sheet

1. **Terms and definitions**

   a. **Asynchronous**—Circuit in which timing depends on the relationship of the elements of the circuit rather than on a master clock signal

   b. **Bit**—A single digit (binary 0 or 1) used to transmit or store information in an electronic logic or computer system

   c. **Byte**—Group of bits—usually eight—that represents a single character or symbol

   Note: Electronic information is normally spoken of in terms of the number of bytes it contains. Because bytes are such small units, the normal units of measure are the *kilobyte* (1024 bytes) and the *megabyte* (1,048,576 bytes).

   d. **Decrement**—To sequentially decrease, as in counting backwards from 10 to 0 by ones

   e. **Gate**—Electronic device that allows input signals to enter and then manipulates them in a prescribed way to produce a single output

   f. **Increment**—To sequentially increase, as in counting from 2 to 20 by twos

   g. **Inverse**—In a mathematical set, an opposite

   h. **Logic**—System of relationships that defines how a set of input signals is related to a set of output signals

   Note: The term *logic* comes from an area of study in reasoning that deals with if-then relationships, such as, "*if* all binary numbers are either 0 or 1 and this binary number is not 1, *then* it must be 0." In electronics, logic refers to the if-then relationships of input and output signals as the signals are manipulated by logic devices—that is, if these signals go in, then this signal will come out.

   i. **Memory**—In electronic devices such as calculators and computers, the areas of the device where information can be stored

   j. **Multivibrator**—An oscillator that does not produce a sinusoidal output waveform

k. **Parallel transmission**—Method of transmitting signals in which several signals are sent at the same time through separate conductors

Note: Parallel transmission or *transfer* is often referred to in terms of how many bits of information are moved in a single transmission. For computers, these are usually in multiples of 8, such as 8-bit, 16-bit, 32-bit, and 64-bit systems.

l. **Serial transmission**—Method of transmitting signals in which signals are sent one after another through a single conductor

m. **Shift register**—Circuit that is capable of storing data or sending it to another, usually adjacent, device

n. **Synchronous**—Circuit in which timing depends on a master clock signal

o. **Volatile memory**—Type of memory in which the information is lost if power is removed from the circuit

p. **Word**—Group of bits or bytes that represent a complete element of information

Note: A word may be a single bit, such as binary 1 representing decimal 1, or a group of bits, such as 1001 0011 0101 representing 935 in binary coded decimal systems.

2. How signals represent information

Note: Early in your studies of electronics you learned that electronic circuits use electricity as signals to convey information. Your studies began with the simplest level of information: applying power turns equipment on, while removing power turns it off. Then you learned about how the signals could be conditioned in various ways to produce different results, such as transistors that act as switches according to the input signal or even feedback. As you begin to study logic devices, you will see that signals can be used in even more sophisticated ways.

a. A signal may be used to represent information directly as a result of its characteristics, such as polarity, voltage, frequency, etc.

Examples: Voltage-controlled or frequency-controlled devices

b. A signal may be used to represent information indirectly so that an individual characteristic or a combination of its characteristics represents a symbol, such as a number, letter, computational sign, etc.

Example: In the binary system, three switches may be positioned *on-off-on* to represent the numbers 1, 0, and 1, which in turn represent the decimal number 5.

Information Sheet

c. The information carried by a signal is either *command and control* information or *data.*

d. *Commands* are instructions that tell equipment what functions to perform.

Examples: Trigger signal on triac, computer commands such as "save"

e. *Control information* includes signals that influence other signals as a result of the equipment's operating conditions.

Examples: Feedback signals, reference signals, modem reset signals

f. *Data* is information that represents language, quantities, images, sound, and other symbols not related to the operation of the equipment.

Examples: Calculator display, computer file, music from a CD, fax

g. Information may be a single pulse or a string of pulses.

Examples: A single *bi*nary digi*t* is a bit, a sequence of bits representing a symbol is a *byte*, and a sequence of one or more bytes that forms one data unit is a *word*

h. Information may be stored, maintained active, or transmitted.

i. Stored Information may be *volatile* or *permanent*.

j. Information stored in volatile memory is lost once power is removed.

k. Information stored in permanent memory can be recovered after power has been removed once power is restored.

l. Information that is maintained in an active state continues to receive power as a signal.

m. Active signals can be combined and routed through various devices so that the output of the device is related to the input signals or to some standard in a specific way that is defined as *logic*.

n. In binary logic circuits, signals that are basically *on* signals over approximately 5 volts are termed *logic high* and represent binary 1, while signals near 0 are termed *logic low* and represent binary 0.

o. Information may be transmitted *serially*—that is, one pulse at a time.

p. Information may be transmitted in *parallel*—that is, several signals are transmitted along separate conductors at the same time.

Information Sheet

3. Numbering systems used in logic circuits

Note: Several numbering systems have been developed or modified for use with logic circuits to make the processing of data simpler. The more common are described below. A key point to remember is that the name of each system includes a base or *radix* that indicates how many symbols are used in the system. Thus, the decimal system, or base 10, has ten symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. *Decimal* comes from the Latin word for ten, as does *decade* meaning 10 years. The binary or base 2 system has two symbols: 0 and 1. *Binary*, like *bicycle* and *bifocals*, comes from a Latin word meaning twice.

a. Binary system (base 2)—Numbering system consisting of the symbols 0 and 1

b. Octal system (base 8)—Numbering system consisting of the symbols 0, 1, 2, 3, 4, 5, 6, and 7

c. Decimal system (base 10)—Numbering system consisting of the symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9

d. Hexadecimal system (base 16)—Numbering system consisting of the symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F

e. Binary coded decimal system (BCD or 8421)—Numbering system consisting of the symbols 0 and 1 arranged in four-bit elements that represent each decimal digit

f. American Standard Code for Information Interchange—Numbering system consisting of the symbols 0 and 1 arranged in seven-bit elements that represent the 26 lowercase letters, 26 uppercase letters, 10 decimal digits, and several special characters, such as punctuation symbols, monetary symbols, and other characters found on a keyboard

Note: The American Standard Code for Information Interchange is usually abbreviated as ASCII and pronounced *ask-ee*. Many computer programs have ASCII codes in their translation files. For example, most word processing programs allow the user to save files in ASCII code. This permits the file to be transferred into a different word processor program with all of the text and some of the format codes saved.

4. Types of logic gates

Note: A logic gate may have one or more inputs. However, the logic gate will output a logic high (1) or a logic low (0) signal. There are numerous ways of describing logic gate functioning. In most of the descriptions on the next page, functions are defined in terms of a logic low output.

Information Sheet

a. NOT gate (inverter)—Provides an output that is the inverse or complement of the input

Example: A binary inverter outputs a 1 for a 0 input

b. AND gate—Combines two or more inputs to produce a single output that will be logic low unless all of the inputs are logic high

c. NAND gate (NOT AND)—Combines two or more inputs to produce a single output that will be logic low only when all of the inputs are logic high

d. OR gate—Combines two or more inputs to produce a single output that will be logic low unless the input signal contains one or more logic highs

e. NOR gate (NOT OR)—Combines two or more inputs to produce a single output that will be logic low unless all of the input signals are logic low

f. XOR gate (exclusive OR)—Combines two or more inputs to produce a single output that will be logic low when all input signals are the same (high or low)

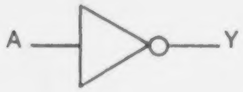
g. XNOR gate (exclusive NOT OR or exclusive NOR)—Combines two or more inputs to produce a single output that will be logic low unless all of the input are the same (high or low)

5. **Logic gate symbols**

Note: Logic statements can be presented in a number of ways. The information below shows the schematic symbol, the logic equation, and a one- or two-input logic table that summarizes the output for different combinations of inputs.

a. NOT gate (inverter)

Note: The circle at the output terminal of the NOT gate and others shown below indicate inversion.

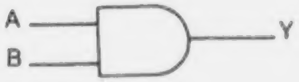


$\overline{A}=Y$

A	Y
0	1
1	0

Information Sheet

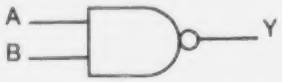
b. AND gate



$AB = Y$

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

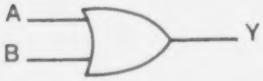
c. NAND gate (NOT AND)



$\overline{AB} = Y$

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

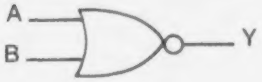
d. OR gate



$A + B = Y$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

e. NOR gate (NOT OR)

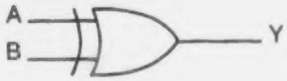


$\overline{A + B} = Y$

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Information Sheet

f. XOR gate (exclusive OR)

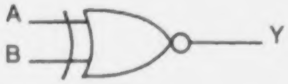


$\overline{A}B + A\overline{B} = Y$

$A \oplus B = Y$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

g. XNOR gate (exclusive NOT OR)



$\overline{A \oplus B} = Y$

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

6. **Types of multivibrator circuits**

Note: Recall that an oscillator that does not produce a sinusoidal waveform is called a relaxation oscillator or *multivibrator*. The multivibrator circuit is usually some variation of an RC-coupled isolator. The circuit may consist of discrete components or discrete components with an op-amp. However, for most computer applications, an IC is used.

a. Multivibrators are classified as *astable* (free-running or clock), *monostable* (one-shot), and *bistable* ((flip-flop).

b. Astable multivibrators produce a rectangular waveform that switches back and forth between a fixed low and a fixed high state.

c. An astable multivibrator will remain in each state for a short period of time that is adjustable through design.

d. Astable multivibrators are used primarily for timing devices and square wave generators.

e. Monostable multivibrators have one stable state.

f. A monostable multivibrator can be switched from its stable state for a short period but will quickly return to the stable state on its own.

g. Monostable multivibrators are used for delay circuits, timing circuits, and for waveshaping.

h. Bistable multivibrators are the most widely used in memory and logic circuits.

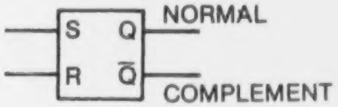
i. Bistable multivibrators have two stable states.

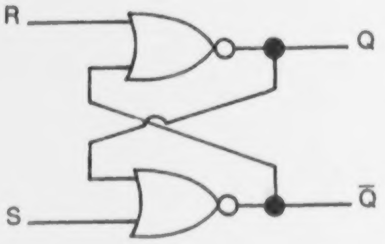
j. A bistable multivibrator will remain in one of its stable states until triggered to switch.

k. Bistable multivibrators are used for counters, shift registers, and storage circuits.

7. **Diagram of a set-reset flip-flop**

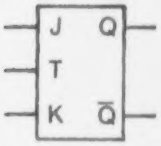
Note: One common type of bistable multivibrator is the *set-reset flip-flop* or *R-S flip-flop* whose two possible outputs are normally referred to as normal (Q) and complement ($\overline{Q}$).

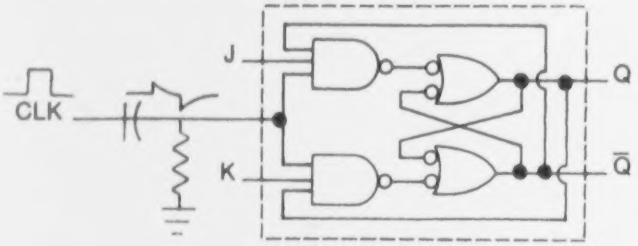




8. **Diagram of a J-K flip-flop**

Note: Another popular bistable multivibrator is the *J-K flip-flop* or *complementing* or *toggle flip-flop*. The J-K flip-flop changes state in response to a clock pulse and provides one output pulse for each two input pulses.



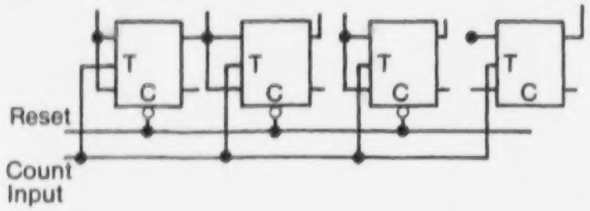


Information Sheet

9. Types of counters

a. Synchronous counter—Each element in the circuit is controlled by the same timing input

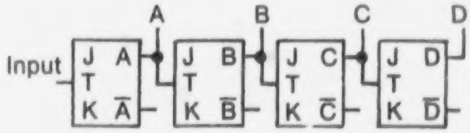
Example:



b. Asynchronous counter—The elements, such as flip-flops, are cascaded so that the output of one device drives the next

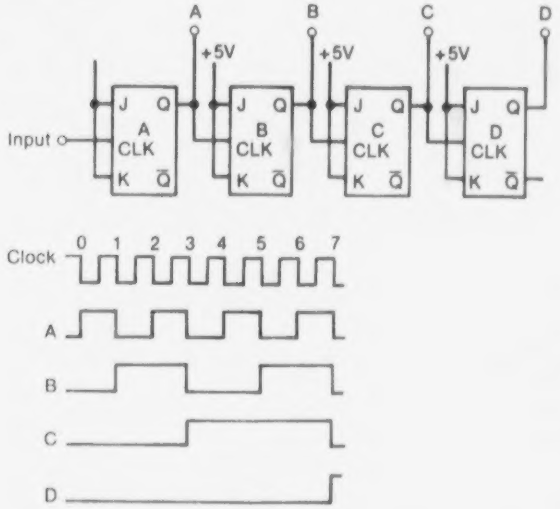
Note: Asynchronous counters are sometimes called *ripple counters.*

Example:



c. Binary counter—The output frequency of each element is one-half of its input

Example:



Information Sheet

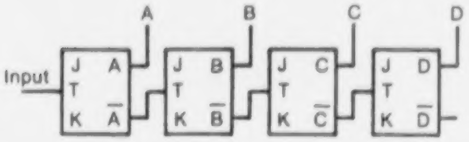
d. Incremental counter—Increases the count by one with each input pulse

Note: Incremental counters are sometimes referred to as *up-counters*. The counters shown for synchronous and asynchronous are both incremental counters.

e. Decremental counter—Counts down instead of up with each input pulse

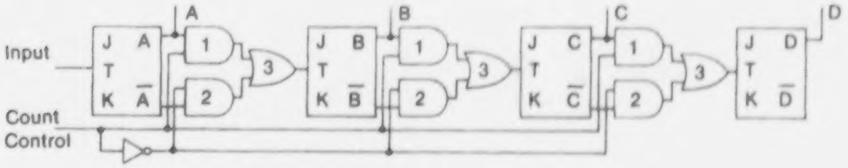
Note: Decremental counters are sometimes referred to as *down-counters*.

Example:



f. Combination counter—Counts either up or down depending on the input from a count control signal

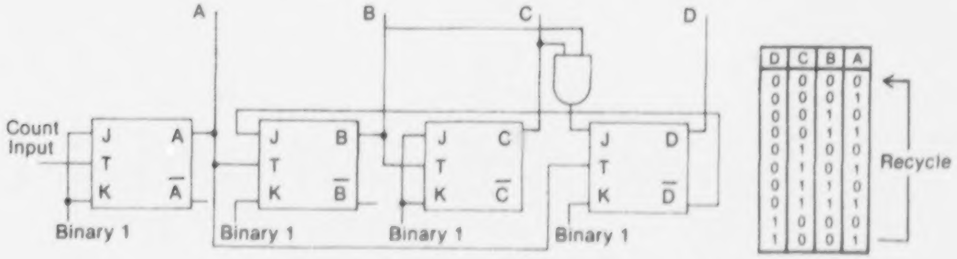
Example:



Count Control Binary 1 - Up
Binary 0 - Down

g. BDC counter—Has ten discrete states that represent the decimal numbers 0 through 9

Example:

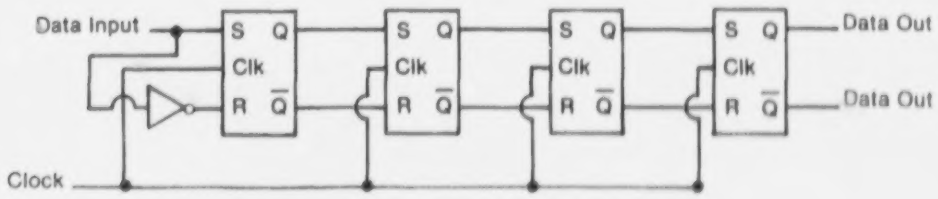


D	C	B	A
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0
1	0	0	1

Information Sheet

10. Diagram of a shift register

Note: A shift register is a series of flip-flops interconnected in such a way that data can be transferred serially from one flip-flop to the next adjacent flip-flop.



11. Functions that can be performed by shift registers

a. Perform arithmetic operations

b. Parallel to serial data conversion

c. Serial to parallel data conversion

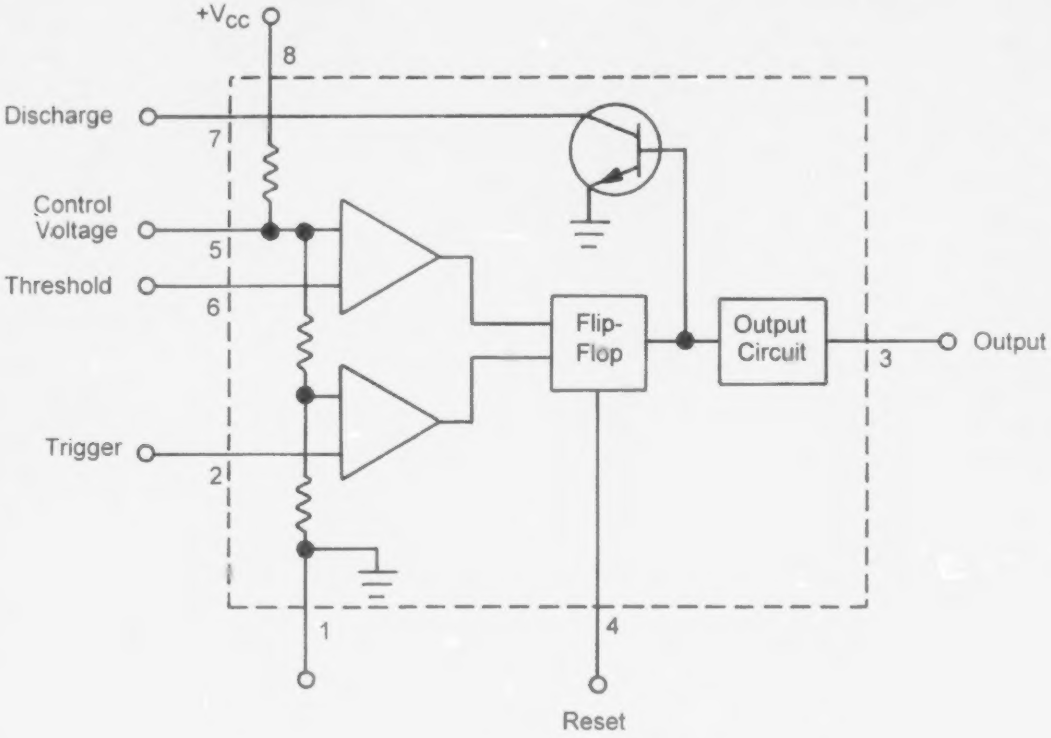
d. Counting

e. Frequency dividing functions

Information Sheet

12. Operation of timing circuits

Note: The LM555 timer is one of the most popular IC timing circuits and is widely used in electronic applications. Because it is typical of basic timer operations, it is used here to illustrate timer operations. Specific functions, pin configurations, specifications, and other features will vary depending on the particular timer.



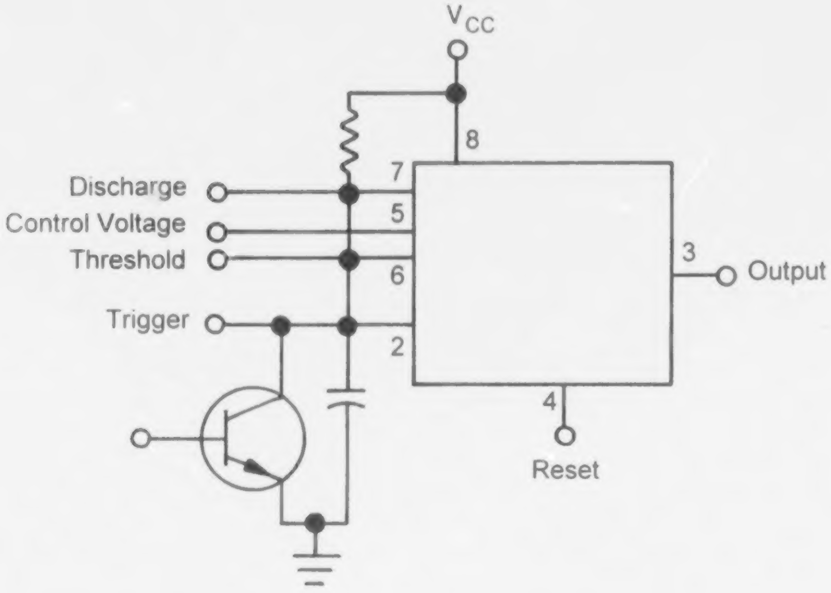
a. The 555 timer consists of two comparators, a bistable multivibrator, a resistor voltage divider, a discharge transistor, and an output amplifier.

b. The timer can be configured for time-delay or multivibrator operation.

c. The timer's output will be a digital, square-wave signal in any configuration.

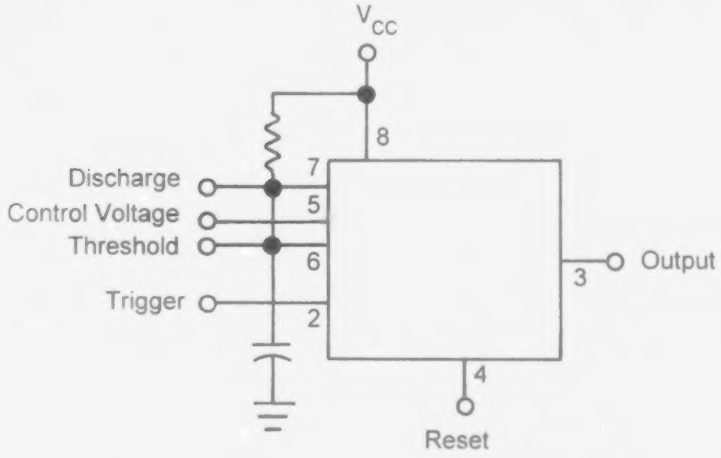
Information Sheet

d. The time-delay configuration is achieved with an external RC circuit and may include a transistor for triggering with time delays of microseconds to hours possible.



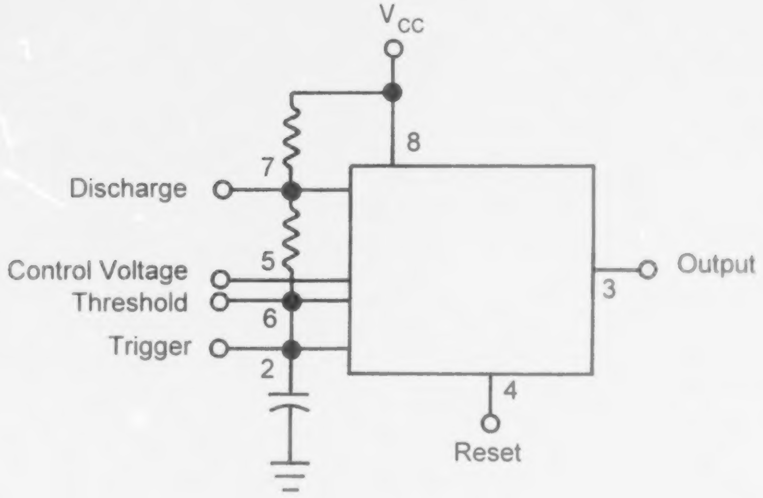
e. Multivibrator operation may be monostable or astable free-running.

f. The monostable multivibrator is configured much like the delay timer without the transistor trigger because triggering is achieved when the input signal drops below one-third of the collector voltage supply of the internal transistor.



Information Sheet

g. The astable multivibrator is configured with the threshold and trigger pins directly coupled so that the external capacitor charges through both external resistors when the internal transistor is switched on and discharges through R_2 when the transistor is off.



13. **Functions of clock and timing circuits**

a. To set the delay time between events

b. To set the duration of events

c. To maintain synchronization of circuits

d. To record the time of occurrence of an event

e. To record the duration of an event

f. To present current time

14. **Functions of arithmetic-logic circuits**

Note: The output of a digital circuit can be described in mathematical terms. For this reason, the output can be used to represent solutions to mathematical equations or the equations can be used to describe the action of the device. The common mathematical functions and representations for digital circuits are those listed below.

a. Addition

b. Subtraction

Information Sheet

c. Multiplication

d. Division

e. Computing the square of a number

f. Computing the square root of a number

g. Boolean algebra

15. Operation of multiplexer circuits

Note: Multiplexers used in digital circuits are normally ICs and are often referred to as *muxes*. A typical mux can handle sixteen input signals.

a. Multiplexing is the process of transmitting through the air or over a link several signals at the same time.

b. The two main methods for achieving multiplexing are *frequency-division multiplexing* (FDM) and *time-division multiplexing* (TDM).

c. Frequency-division multiplexing is commonly used for modulated radio transmissions to allow simultaneous broadcast of the carrier and sideband signals.

d. Digital transmissions over hard links are usually multiplexed through time-division.

e. In semiconductor multiplexer circuits, input devices share a common output and clock pulses regulate TDM transmissions.

f. For each clock pulse, one device has an *open channel* and its output is carried over the transmission link.

g. During the next clock pulse, another device transmits its output signal, and the process continues with each active input device being enabled sequentially by the clock pulses.

h. The period during which a device may transmit is called its *time slot*.

i. The number of times that a single channel has a time slot within a given period, such as a second or microsecond, is called the *sampling frequency* or *sampling rate*.

j. Multiplexers can be configured so that some signals are sampled more often than others to allow for differences in signal speed or importance.

Information Sheet

k. Multiple multiplexers can be interconnected to produce a single output in four common configurations:

- *Direct coupling* configures the multiplexers so that the output of one serves as the input to a second and the circuit output is the output of the second mux.

- *Parallel configuration* uses a counter circuit to enable the multiplexers in succession so that the circuit output signal comes from one mux at a time in rotation.

- *Pyramidal configuration* uses two banks of muxes and two counters so that the first counter controls the outputs of the first bank of muxes, which serve as the inputs to the second bank of mux(es) whose output is controlled by the second counter.

- *Two-level configuration* uses two banks of muxes with each mux in the first bank being controlled by a different counter so that the time slot moves from mux to mux for one signal each with their output going to the second bank of muxes.

  Note: In the parallel and pyramidal configurations, the 16 signals of one mux are output before the time slot moves to the next mux, whereas in the two-level design the time slot passes to the next mux after each signal transmission.

l. The two common ways of conditioning signals for TDM are *pulse amplitude modulation* (PAM) and *pulse code modulation* (PCM).

m. In pulse amplitude modulation, the height and polarity of the signal at the time of sampling is transmitted and is referred to as the *instantaneous amplitude*.

n. The major drawback of PAM is that if the multiplexed signal becomes distorted during transmission, then the output will provide the wrong information.

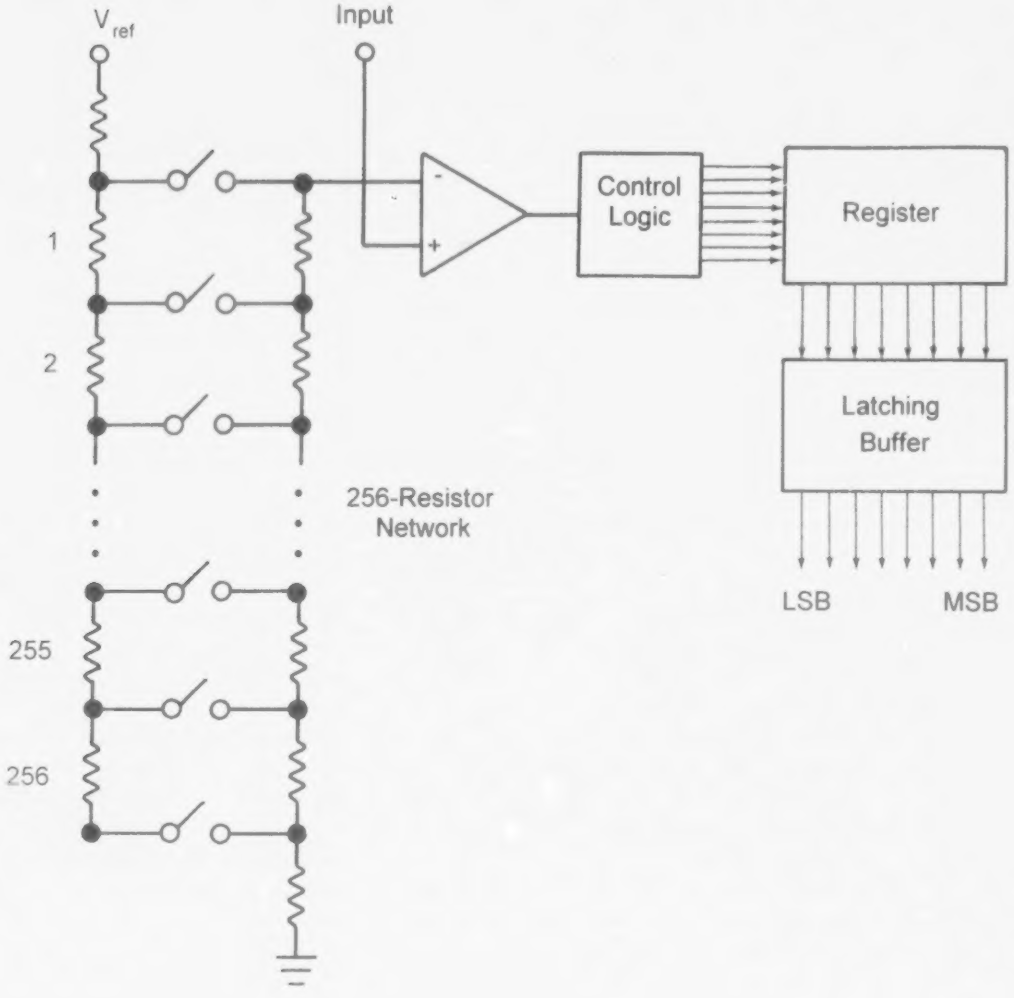
o. PCM overcomes this problem by converting pulse amplitude into a coded value, which is transmitted to represent the amplitude.

p. *Demultiplexing* is the conversion of the signals at the other end of the transmission link.

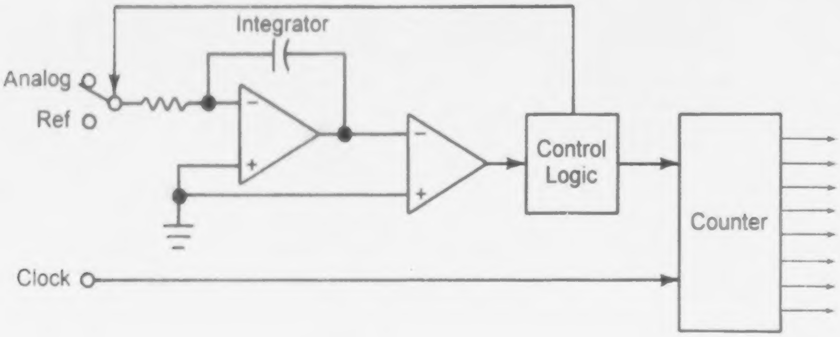
Information Sheet

16. Analog/digital conversion circuits

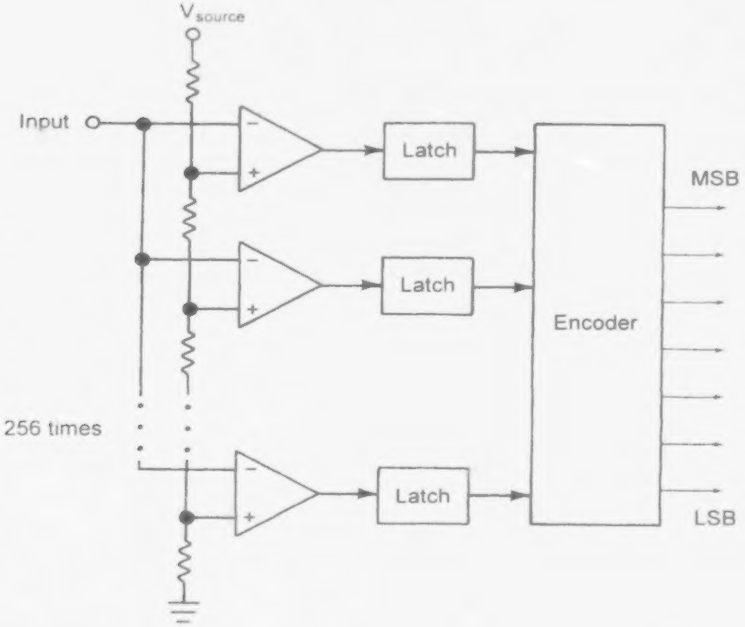
a. Successive approximation—Compares analog input voltage to internal reference voltage divider tap and generates a digital output each time a match is obtained between the input and the reference signal; moderately fast



b. Dual slope—Uses integrator and comparator networks to convert a monitored input signal to a digital output based on the time it requires the integrator output to return to a reference voltage level, such as 0 volts; provides good noise immunity but is relatively slow



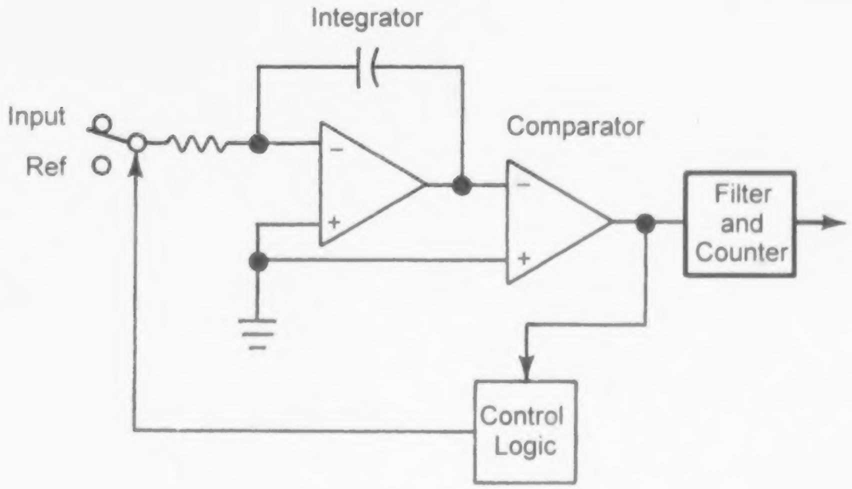
c. Flash—Uses two clock signals and a network of 256 resistors and comparators to provide simultaneous conversion; very fast conversion but requires space and power



Information Sheet

d. Sigma-delta—Uses an internal one-bit analog-to-digital converter tied to the output of a series integrator and comparator to provide a feedback signal to the integrator and whose final output is filtered to provide an average of the internal digital pulses; provides good speed while recognizing very low input signal levels with good resolution

Note: The process of digital pulse averaging is referred to as *decimation* and is provided in the sigma-delta A/D converter by a digital filter and decimator.



17. Operation of encoder/decoder circuits

a. The purpose of an encoder is to convert a signal characteristic into a specific code, such as amplitude into binary code.

b. The purpose of a decoder is to convert a coded signal into its characteristic signal, such as converting a binary code into a sine wave.

c. One of the most common ways of encoding is to use a multiplexed signal and assign coded values for several positive and negative levels of amplitude.

Example:

Amplitude	Binary Code
+1.75 volts	0111
+1.50 volts	0110
+1.25 volts	0101
+1.00 volts	0100
+0.75 volts	0011
+0.50 volts	0010
+0.25 volts	0001
0.00 volts	0000
-0.25 volts	1000
-0.50 volts	1001
-0.75 volts	1010
-1.00 volts	1011
-1.25 volts	1100
-1.50 volts	1101
-1.75 volts	1110

d. By doing the same translation in reverse, a decoder is able to convert the coded signal back into the multiplexed signal.

18. Noise problems

a. Digital circuits can experience problems as a result of either internally or externally generated noise.

b. Noise may be static or transient.

c. Internally generated noise may result from the relationship of components to each other.

Note: Shielding, filter capacitors, and other techniques are often used to reduce interference between components.

d. Internally generated noise may result from circuit board traces being too close to each other or because of traces running parallel to each other.

Note: Less noise is likely if traces are properly spaced or if they run perpendicular to each other in separate layers of the circuit board.

e. Internally generated noise may result from poor or improper grounding.

f. Many logic circuit noise problems result from the circuit power supply.

Note: Many circuit boards use a power plane instead of power traces or the fan-in and fan-out methods described on the next page.

Information Sheet

g. One method of reducing power-supply induced noise is to use a fan-in power distribution, which provides separate power traces to a group of ICs.

h. Another method of reducing power-supply induced noise is fan-out distribution, which routes power to a single IC and then to other ICs in that group.

i. Noise can also result from trying to drive a digital circuit too fast, which increases the power requirements and reduces the resolution of the analog input.

19. Characteristics of IC logic families

Note: TTL and CMOS are probably the most popular logic families in use today. Many more exist other than those listed here, such as transistor-resistor logic (TRL), transistor-coupled logic (TCL), complementary transistor logic (CTL), diode-transistor logic (DTL), and current mode logic (CML).

a. Transistor-transistor logic (TTL)

- Uses two transistors often in a bipolar IC
- Costs relatively little
- Used in a wide variety of devices

b. Emitter-coupled logic (ECL)

- Uses nonsaturating bipolar transistors
- High speed
- Moderate cost
- Relatively high power consumption

c. Metal-oxide semiconductor (MOS) devices

- Simple construction
- Permits construction of small circuits
- High impedance
- Relatively low power consumption
- Relatively slow speed

Information Sheet

d. Complementary-metal-oxide semiconductor (CMOS) devices

- Overall characteristics generally well balanced
- Low power consumption
- Excellent noise immunity
- Fairly high speed

20. Characteristics of electronic displays

Note: The characteristics of displays used on electronic equipment are important for several reasons. First, characteristics such as those listed below determine whether a display is suitable for a specific application. Secondly, measurements related to these characteristics may be part of the troubleshooting procedures for a display or may be an indication of a problem with the device or other circuitry, such as the power supply.

a. Contrast—Degree to which adjacent areas of a display can be distinguished from each other

Example: Books are generally printed with black ink on white paper for maximum contrast.

b. Resolution—Degree to which fine details can be duplicated on the display

c. Brightness—Amount of light produced by the display

d. Pixels per inch—Measurement of how many dots of light are used to create the display picture

Note: Pixel is short for *picture element*. Displays that show more than symbols such as letters and numbers generally use clusters of small lamps to create their images. Points of light or dark are created by whether or not the lamp is on or by how much power is directed to the lamp. These displays achieve resolution and, to a degree, contrast through their pixel density. Such displays are often measured by their diagonal size and their pixel area, such as 640 x 640 pixels.

e. Stability—Ability of the display to maintain an output that does not flicker or float about the display area

f. Viewing angle—Range of perspectives from which an operator can read a display

Information Sheet

21. Types of displays

a. Light-emitting diode display—Used for calculators, watches, and other devices where power and cost may be limited and resolution, brightness, contrast, and color are not important

b. Monochrome liquid crystal display—Used for clock radios, portable computers, and other devices where power and cost are less restricted and moderate brightness is required; usually presented in red, amber, green, or gray and capable of high contrast

c. Color liquid crystal display—Used for portable computers, portable video games, and other devices where color is more important than contrast and brightness; generally consists of pixel clusters of red, blue, and yellow (or green) that combine to make a single point of light so that resolution is limited

d. Active matrix liquid crystal display—Used for portable computers, instrumentation displays, and other devices where high contrast and resolution are required; uses enhanced lamp drivers that allow greater control of individual pixels

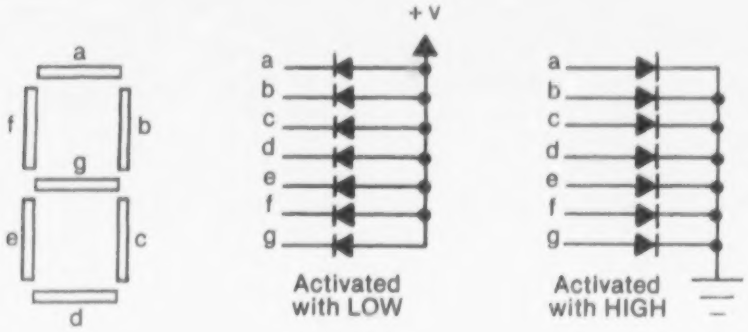
e. Cathode ray tube—Used in televisions, test equipment, computers, and other devices where size and power are not as restricted as with most portable equipment

f. Pixie tube—Used to provide numerical readouts for some test equipment and instrumentation; consists of a gas-filled tube having ten cold cathodes under a disk-shaped anode so that a different digit is illuminated with each cathode as current shifts from one to another

Information Sheet

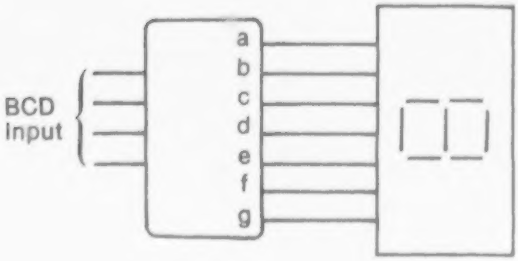
g. Seven-segment display—Used to provide numerical readouts in various devices; usually constructed with LEDs or LCDs

Example: Seven-segment display with BCD decoder



Activated with LOW

Activated with HIGH



Logic Devices and Circuits
Unit 1

Assignment Sheet 1—Convert Octal Numbers to Decimal Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	Rating
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________

Note: Each correct answer is worth 10 points.

Introduction: The various numbering systems used with logic devices and computer systems are convenient tools for simplifying the processing of information in such circuits. However, the fact that several such systems exist can cause problems. It is sometimes necessary to convert from one system to another in order to interpret test results, do programming, understand data, and to perform other tasks. The conversions are generally straightforward once one understands the relationships among the numbering systems. In this series of assignment sheets, you will receive practice in making these conversions, beginning with the conversion between octal and decimal numbers.

The octal system uses the digits 0 through 7 and are indicated as base 8 numbers. The decimal system uses the digits 0 through 9 and are designated as base 10 numbers. Because you are most familiar with decimal numbers, it may help you to grasp octal numbers a little better if we compare the first 20 positive decimal numbers with the first 20 positive octal numbers, as shown in the chart below:

Decimal	Octal
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	10
9	11
10	12
11	13
12	14
13	15
14	16
15	17

Assignment Sheet 1

16	20
17	21
18	22
19	23

As you can see, the octal system does not use a digit above 7. Thus the octal number after 77 is 100 and the octal number after 777 is 1000.

In all of the numbering systems, the value of a digit is based on its position in the written number. For example, the octal number 5417.23_8 has the following positional values:

+3	+2	+1	0	-1	-2
5	4	1	7	2	3

These same positional values apply to each of the numbering systems and extend to infinity on both sides of the decimal point. The farther a digit is positioned to the left, the greater its impact on the value represented. For example, if a value is 24.3 volts, it is more important to know that there is a 2 in the +1 position than to know that there is a 3 in the -1 position, as an estimate of 20 volts is more accurate than an estimate of 0.3 volts. This concept is important because of the use of codes to represent values in digital electronics. For this reason, the extreme right and left positions have special designations. The number in the far left position is referred to as the *most significant bit* (m.s.b.), while the number in the far right position is called the *least significant bit* (l.s.b.).

The positional values become clearer as you work with actual numbers, so let's begin by converting the base 8 number 417_8 to its decimal equivalent. This is done by multiplying each octal positional digit by 8 raised to that positional power and then adding the products together. Thus,

$$\begin{aligned} 417_8 &= (4 \times 8^2) + (1 \times 8^1) + (7 \times 8^0) \\ &= (4 \times 64) + (1 \times 8) + (7 \times 1) \\ &= 256 + 8 + 7 \\ &= 271_{10} \end{aligned}$$

We can verify our number list above by converting the octal number 22 to a decimal number:

$$22_8 = (2 \times 8^1) + (2 \times 8^0) = (2 \times 8) + (2 \times 1) = 16 + 2 = 18_8$$

This process of multiplying and adding numbers may seem strange at first, but you have actually done the same thing with decimal numbers for most of your life. For example, the decimal number 6,791.2 actually means 6 thousands and 7 hundreds and 9 tens and 1 unit and two tenths. If we write this in the format used above for the octal numbers, it would look like this:

Assignment Sheet 1

$$\begin{aligned} 6{,}791.2_{10} &= (6 \times 10^{3}) + (7 \times 10^{2}) + (9 \times 10^{1}) + (1 \times 10^{0}) + (2 \times 10^{-1}) \\ &= (6 \times 1{,}000) + (7 \times 100) + (9 \times 10) + (1 \times 1) + (2 \times 0.1) \\ &= 6{,}000 + 700 + 90 + 1 + 0.2 \\ &= 6{,}791.2 \end{aligned}$$

Directions: Convert the octal numbers listed to decimal numbers. Write your answers in the blanks provided with each number.

1. 400_8 ______________________________
2. 647_8 ______________________________
3. 24_8 ______________________________
4. 2113_8 ______________________________
5. 5671_8 ______________________________
6. 333_8 ______________________________
7. $123\ 777_8$ ______________________________
8. 456_8 ______________________________
9. 24405_8 ______________________________
10. $441\ 623_8$ ______________________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 2—Convert Decimal Numbers to Octal Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: In the previous assignment sheet, you practiced converting octal numbers to decimal numbers. In this assignment sheet, you are asked to make the conversion the other way.

To convert the other way, base 10 numbers are divided by 8 to determine the remainder of each operation. The remainders are then assembled by position to form the octal number. For example, to convert the decimal number 486_{10} to an octal number, the process would be

486_{10} = 486 ÷ 8 = 60, with a remainder of 6

60 ÷ 8 = 7, with a remainder of 4

7 ÷ 8 = 0, with a remainder of 7

7 4 6_8

So 486_{10} is equal to 746_8. Just follow these procedures for the problems in this assignment sheet.

Directions: Convert the decimal numbers listed to octal numbers. Write your answers in the blanks provided with each number.

1. 48_{10} ______________________
2. 6464_{10} ______________________
3. 320_{10} ______________________
4. 5401_{10} ______________________
5. 999_{10} ______________________

Assignment Sheet 2

6. 12075_{10} ________________________________

7. $379\ 862_{10}$ ________________________________

8. 2177_{10} ________________________________

9. 229_{10} ________________________________

10. 1365_{10} ________________________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 3—Convert Decimal Numbers to Binary Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: The most common number system in logic and computer devices is the binary system. Because the numbering system that most of us use on a daily basis is the base 10 system, conversions from decimal to binary are frequently required. The binary system has only two digits: 0 and 1. All numbers can be written with these two digits if you understand the binary system. Let's look at a comparison of the first twenty numbers in the two systems:

Decimal	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111
16	10000
17	10001
18	10010
19	10011

Assignment Sheet 3

To convert a decimal number to a binary number involves a series of divisions by 2, with the remainder at each operation serving as a digit in the binary number beginning with the far right position. For example, to convert decimal 19 to binary:

19 ÷ 2 = 9, remainder 1
9 ÷ 2 = 4, remainder 1
4 ÷ 2 = 2, remainder 0
2 ÷ 2 = 1, remainder 0
1 ÷ 2 = 0, remainder 1

Thus, decimal 19 equals: 1 0 0 1 1

Note that only whole numbers are used in the division operations—that is, 1 divided by 2 does not equal 0.5 but is equal to 0 with a remainder of 1.

Directions: Convert the decimal numbers listed to binary numbers. Write your answers in the blanks provided with each number.

1. 74 ______________________
2. 186 ______________________
3. 555 ______________________
4. 1214 ______________________
5. 12,219 ______________________
6. 10^3 ______________________
7. 31 ______________________
8. 1.2M ______________________
9. 99 ______________________
10. 2020 ______________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 4—Convert Binary Numbers to Base Ten Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: There are two methods commonly used to convert binary numbers to decimal numbers. You will learn the traditional way in this assignment sheet and a technique called the *double-dabble method* in Assignment Sheet 5. One of the reasons that two methods have developed is that the conversion of binary numbers into the system we commonly use—that is, decimal system—is a common requirement in the electronics trade. Technicians who have worked with these systems for some time can mentally convert numbers between systems without calculating them. But until a person has that level of skill—and even for the experienced technician for numbers that are rarely encountered—these calculation methods are the easiest and surest way of making the conversions.

The conventional method for converting binary numbers to decimal numbers is similar to the method that you learned for converting octal numbers to decimal numbers. It involves multiplying the positional digits by their base 2 value. For example, converting binary 110 to its decimal equivalent is done this way:

$$\begin{aligned} 110_2 &= (1 \times 2^2) + (1 \times 2^1) + (0 \times 2^0) \\ &= (1 \times 4) + (1 \times 2) + (0 \times 1) \\ &= 4 + 2 + 0 \\ &= 6_{10} \end{aligned}$$

Remember that each position in the number represents a power to which 2 is raised, and that number becomes the multiplier for each digit in the decimal number.

Directions: Convert the binary numbers listed to decimal numbers. Write your answers in the blanks provided with each number.

1. 10 ______________________________

2. 111 ______________________________

Assignment Sheet 4

3. 1101 ______________________________

4. 10001 ______________________________

5. 1110101 ______________________________

6. 10000001 ______________________________

7. 11011 ______________________________

8. 11111 ______________________________

9. 101 ______________________________

10. 110 000 111 ______________________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 5—Use the Double-Dabble Method to Convert Binary Numbers to Decimal Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: Some people find that the double-dabble method is an easier way for them to convert binary numbers to decimal numbers as compared to the conventional method. You can practice it in this assignment sheet and decide for yourself which technique you prefer.

You have probably noticed that binary numbers other than 0 begin with 1, because all binary numbers that are greater than 1 have at least one group of 2s, which is what the first digit represents. Thus, the first step in the double-dabble method is to write a 1 over that left-most digit. The next step depends on whether the digit to the right of the first digit is a 1 or a 0. If the second digit is 0, double the number that you wrote over the preceding digit and write it above the zero. If the second digit is a 1, double the number that you wrote over the preceding digit, add 1, and write it over the second digit. Thus, you are going to write either a 2 (2 x 1) or a 3 ([2 x 1] + 1) over the second digit. Continue this process for each digit, either doubling the preceding number if the digit is a 0 or doubling it and adding one if the digit is a 1. The number recorded over the right-most digit should be the decimal equivalent.

Let's look at the binary number 10101 as an example. Begin by recording a 1 above the initial digit in the number:

1
1 0 1 0 1

The next number is a 0, so we simply double the number recorded above the first digit. One doubled is 2, so we write a 2 above the second digit.

1 2
1 0 1 0 1

The next digit is a 1, which means that we double the previous number that we wrote down and add 1. That would give us 5 because 2 times 2 plus 1 is 5. Write a 5 over the third digit.

1 2 5
1 0 1 0 1

Assignment Sheet 5

The next digit is another 0, so we just double the previous number that we wrote and record 10 (2 x 5) over the fourth digit.

1 2 5 10
1 0 1 0 1

This brings us to the last digit. Since the last digit is a 1, we double the 10 we wrote down and add 1, giving us 21. Because this is the last digit, this result should be the decimal equivalent and 21 is, indeed, the base 10 equivalent of 10101.

1 2 5 10 21
1 0 1 0 1

Try the double-dabble method on the following binary numbers and see which method you prefer.

Directions: Convert the binary numbers listed to decimal numbers using the double-dabble method. Write your answers in the blanks provided with each number.

1. 101 ____________________
2. 110011 ____________________
3. 100100 ____________________
4. 1101101 ____________________
5. 100000001 ____________________
6. 100000010 ____________________
7. 1111111 ____________________
8. 10110111 ____________________
9. 10011000 ____________________
10. 10001000 ____________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 6—Convert Binary Numbers to Octal Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	Rating
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________

Note: Each correct answer is worth 10 points.

Introduction: As you have probably observed, binary numbers can quickly become cumbersome to work with and confusing due to the strings of 1s and 0s. For these reasons, many people working in scientific and technical fields like to substitute octal numbers for binary numbers. Your first reaction may be to think that such a process must be very confusing, but in fact the binary to octal conversion is one of the easiest among the numbering systems presented here. The reason that this method is easy is because 2^3 is 8. This relationship between binary and octal numbers allows us to substitute an octal number for each group of three binary numbers.

Take the binary number 100101001, for example. To convert it to an octal number, we break it into groups of three digits beginning on the right. That gives us:

100 101 001

Each set of three numbers is equivalent to one of the eight octal digits. If we correlate the first eight binary numbers and the octal digits, we find these equivalents:

Octal	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111

Thus, the three equivalent octal digits are 4, 5, and 1, giving us the octal number 451_8.

Notice that the binary numbers 0 through 11 have zeroes added in front of them to make them three-digit figures. Similarly, if the number of digits in a binary number is not evenly divisible by 3, add enough zeroes to the front of it to make it divisible by 3. For example, if the binary number is 11011, insert a 0 on the left end of the number to make it divisible by 3 and then treat

Assignment Sheet 6

it as 011, 011. Its octal equivalent would be 33_8.

Directions: Convert the binary numbers listed to octal numbers. Write your answers in the blanks provided with each number.

1. 10 ____________________
2. 111 ____________________
3. 1101 ____________________
4. 10001 ____________________
5. 111011 ____________________
6. 1000000 ____________________
7. 111000111 ____________________
8. 10101 ____________________
9. 110001 ____________________
10. 10101100 ____________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 7—Convert Octal Numbers to Binary Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: It has probably already occurred to you that the conversion of octal numbers to binary numbers is likely to be as simple as converting binary numbers to base 8 figures. This is the case. Simply substitute a three-digit binary number for each digit of the octal number and then drop any zeroes to the left of the initial 1. For example, convert 702_8 to a binary number.

$7 = 111_2$

$0 = 0_2 = 000_2$

$2 = 10_2 = 010_2$

Thus, 702_8 is equal to the binary number 111000010. As another example, converting 1503_8 to binary would be done this way:

$1 = 1_2$

$5 = 101_2$

$0 = 0_2 = 000_2$

$3 = 11_2 = 011_2$

So octal 1503 is the same as binary 1101000011. Some technicians go ahead and record 1_2 as 001_2 so that each octal number is given a three-digit equivalent, and this practice may be helpful to you. However, if you add zeroes to an initial digit less than octal 4, remember to remove them when you record the binary number.

Assignment Sheet 7

Directions: Convert the octal numbers listed to binary numbers. Write your answers in the blanks provided with each number.

1. 1177 ______________________
2. 1010 ______________________
3. 56 ______________________
4. 33154 ______________________
5. 111001 ______________________
6. 7741 ______________________
7. 52525 ______________________
8. 302 ______________________
9. 27 ______________________
10. 22222 ______________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 8—Convert Binary Numbers to Hexadecimal Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	Rating
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: In Unit 2, you will do programming for microcomputers using a programming format called *machine language*. Machine language is a way of providing instructions to a computer. Machine language uses the hexadecimal numbering system. For this reason, electronics technicians who work with computer programs are often required to work with the hexadecimal system. The hexadecimal system consists of 16 symbols. The first ten are the digits 0 through 9, and the remaining hexadecimal symbols are the first six letters of the alphabet, A through F. Let's compare the first twenty decimal numbers with the first twenty hexadecimal numbers:

Decimal	Hexadecimal
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	A
11	B
12	C
13	D
14	E
15	F
16	10
17	11
18	12
19	13

At first glance, it may appear that the hexadecimal system is the same as the decimal system except a string of letters is thrown in between 9 and 10. In reality, the two-digit hexadecimal numbers show the values of two groups of numbers. The first digit represents the number of

Assignment Sheet 8

groups of 16 and the second digit represents the remainder. Thus, 10_{16} indicates one group of 16 and a remainder of 0, representing decimal 16. The hexadecimal number FF—the largest two-digit hexadecimal number—represents fifteen groups of 16 with a remainder of 15 or the decimal number 255 ([15 x 16] + 15). Thus, it is fairly easy to convert between decimal and hexadecimal number and vice versa. You simply divide or multiply by 16 and account for the remainder.

The more common operations for electronic technicians are conversions between hexadecimal and binary numbers because hexadecimal is used for machine language programming but is generally converted to binary numbers for actual use in the computer. The process is similar to that used for octal number conversions with binary numbers except that the binary numbers are manipulated in groups of four digits rather than three digits because 16 is equal to 2^4. Thus, to convert the binary number 1100101001010111 to hexadecimal, the process would be:

Binary 4-bit groups:	1100	1010	0101	0111
	↓	↓	↓	↓
Hexadecimal:	C	A	5	7

As with the process for octal numbers, begin grouping at the right and, if the binary number is not divisible into four-digit groups evenly, add zeroes to the left end to make the groups evenly divisible. Thus, binary 10011 would become

0001	0011
↓	↓
1	3

Apply these procedures to the problems presented in this assignment sheet.

Directions: Convert the binary numbers listed to hexadecimal numbers. Write your answers in the blanks provided with each number.

1. 111100 ____________________
2. 11001101 ____________________
3. 1010111 ____________________
4. 101000 ____________________
5. 11110001 ____________________
6. 11010100 ____________________
7. 1000000 ____________________
8. 1110111 ____________________

Assignment Sheet 8

9. 1111 ____________________

10. 1010101010 ____________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 9—Convert Hexadecimal Numbers to Binary Numbers

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: Programmers sometimes find errors in their work. For instance, a transistor may not switch on when it should. This problem may be traced back to the fact that the transistor was not given the right signal to drive it on. The error could be as simple as having entered the wrong hexadecimal code during the machine language programming. To find this problem, it may be necessary to examine the binary codes to which the computer responds to the hexadecimal code in which the program was written. This is an example of a case in which a technician may be required to convert hexadecimal numbers to binary numbers. Another example is that some components are programmed directly in hexadecimal, which may require program translations or other conversions.

The conversion from hexadecimal to binary is simply the reverse of converting binary numbers to base 16 numbers. Each hexadecimal digit in the number is converted into its four-digit binary equivalent. Thus, the hexadecimal number B4E is converted as follows:

$B_{16} = 1011_2$

$4_{16} = 100_2 = 0100_2$

$E_{16} = 1110_2$

So, the binary equivalent of hexadecimal B4E is 101101001110.

Directions: Convert the hexadecimal numbers listed to binary numbers. Write your answers in the blanks provided with each number.

1. 1F ______________________
2. 3E ______________________
3. 3A ______________________
4. 21 ______________________

Assignment Sheet 9

5. 28 ____________________

6. 84 ____________________

7. C3 ____________________

8. 77 ____________________

9. AAA ____________________

10. 12D ____________________

Logic Devices and Circuits
Unit 1

Assignment Sheet 10—Complete Logic Tables

Name ______________________________ Overall Rating ____________

Evaluation criteria	Rating
• Directions have been followed	________
• Minimum of 85 percent of answers are correct	________
Note: Each correct answer is worth 4.8 points.	

Introduction: To understand the output of a logic gate, the technician must know what the input signal is and what the gate does to that signal. In most cases, a gate will have more than one input. Thus, the output will also depend on the combination of inputs—how many and which ones are high and which are low. A systematic way of summarizing the outputs of a logic gate is called a *logic table* or a *truth table*. The term *truth* comes from the philosophical discipline called logic and the method of reasoning known as *syllogisms*. A syllogism is a statement of deductive reasoning to arrive at the truth. For example, if the statement "every student in this electronics course is exceptionally bright" is true based on some definition of *exceptionally bright*, then deductively we can say, "You are a student in this electronics course; therefore, you are exceptionally bright."

Logic gates work in the same way. For instance, a NOT gate is an inverter. If a logic low (binary 0) signal goes through a NOT gate, the output will be a logic high signal (binary 1). A syllogism for this would be: "NOT gates invert signals. This input signal is low and has gone through a NOT gate; therefore, the output signal is high."

Truth tables show all the "if-thens" of inputs and outputs. In the case of an AND gate, the output will be low unless all of the inputs are high. This can be summarized by the statements: "**If** any of the input signals for an AND gate is low, **then** the output will be low. **If** all of the input signals for an AND gate are high, **then** the output will be high." Thus, if you have an AND gate with a dozen signals and you determine that one signal is low, you do not need to check the rest of the inputs to know whether the output signal is high or low. On the other hand, if you find that the first input signal is high, you will not be able to predict that the output is high without first verifying that the other inputs are high.

Logic tables summarize the output for each possible combination of input signals. Based on what you know about logic gates, you should be able to complete the entries in the logic tables in this assignment sheet.

Assignment Sheet 10

Directions: Study the logic gate truth tables below. For each type of gate listed, complete the truth table to show the output for each combination of input signals. Write your answers in the spaces provided in each table.

1. **AND gate**

	A	B	C	Y
a.	0	0	0	
b.	0	0	1	
c.	0	1	0	
d.	1	0	0	
e.	0	1	1	
f.	1	1	0	
g.	1	0	1	
h.	1	1	1	

NOR gate

	A	B	C	Y
i.	0	0	0	
j.	0	0	1	
k.	0	1	0	
l.	1	0	0	
m.	0	1	1	
n.	1	1	0	
o.	1	0	1	
p.	1	1	1	

2. **NAND gate**

	A	B	C	Y
a.	0	0	0	
b.	0	0	1	
c.	0	1	0	
d.	1	0	0	
e.	0	1	1	
f.	1	1	0	
g.	1	0	1	
h.	1	1	1	

OR gate

	A	B	C	Y
i.	0	0	0	
j.	0	0	1	
k.	0	1	0	
l.	1	0	0	
m.	0	1	1	
n.	1	1	0	
o.	1	0	1	
p.	1	1	1	

3. **XNOR gate**

	A	B	C	Y
a.	0	0	0	
b.	0	0	1	
c.	0	1	0	
d.	1	0	0	
e.	0	1	1	
f.	1	1	0	
g.	1	0	1	
h.	1	1	1	

XOR gate

	A	B	C	Y
i.	0	0	0	
j.	0	0	1	
k.	0	1	0	
l.	1	0	0	
m.	0	1	1	
n.	1	1	0	
o.	1	0	1	
p.	1	1	1	

Logic Devices and Circuits
Unit 1

Assignment Sheet 11—Apply Boolean Operations to Minimizing Logic Circuits

Name ____ Overall Rating __________

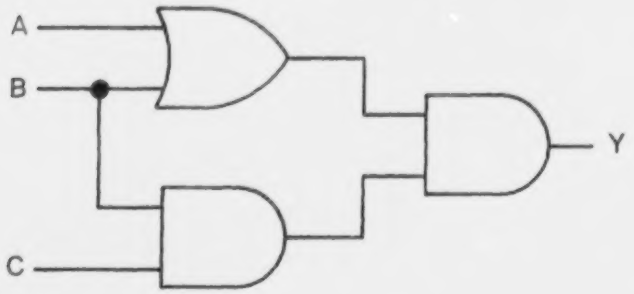
Evaluation criteria	Rating
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: In the mid-1800s, George Boole published his first works on a system of mathematics dealing with sets that became known as Boolean algebra. Nearly 90 years later, engineer Claude Shannon realized that Boole's system would work well in describing certain electrical relationships. Today, technicians and engineers use Boolean theorems and related concepts to simplify the complex relationships between input signals and output signals in logic circuits, particularly combinational logic circuits.

Only by understanding the effects of combining gates can a technician determine whether a logic circuit response is correct.

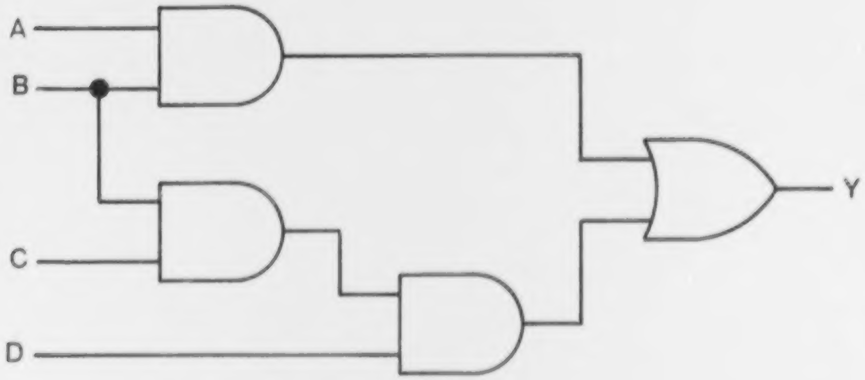
Directions: Study the logic circuits below and on the following pages. Use Boolean algebra to minimize each circuit so that you can determine its output. Write your answers on the blanks beside each schematic.

1. ____________________

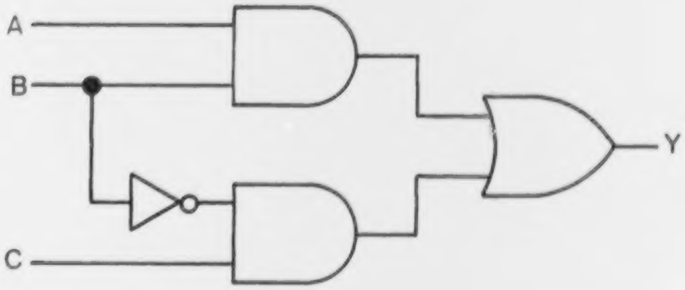


Assignment Sheet 11

2. ____________________

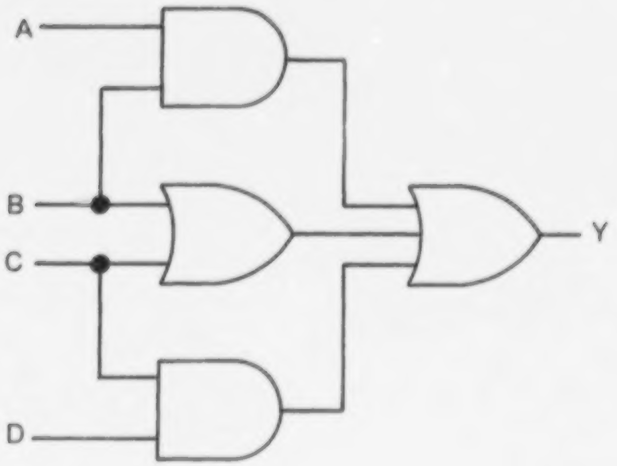


3. ____________________

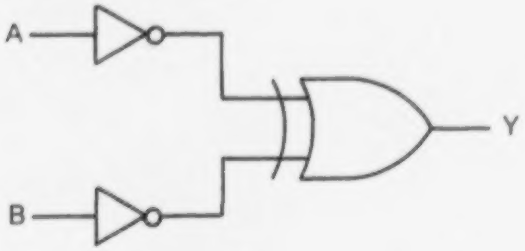


Assignment Sheet 11

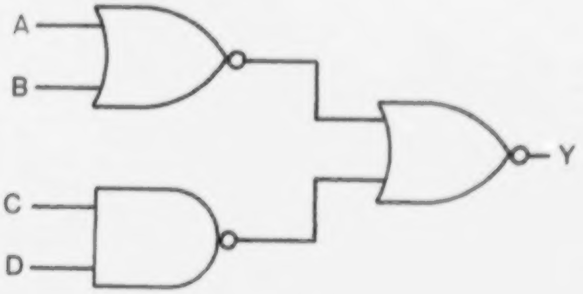
4. ____________________



5. ____________________

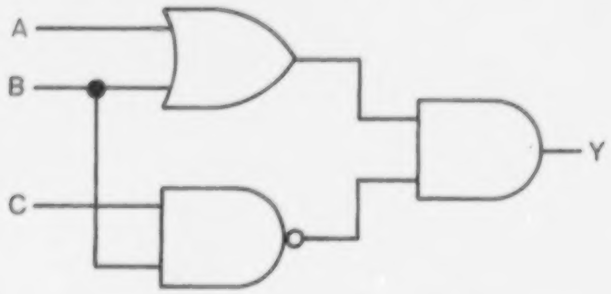


6. ____________________

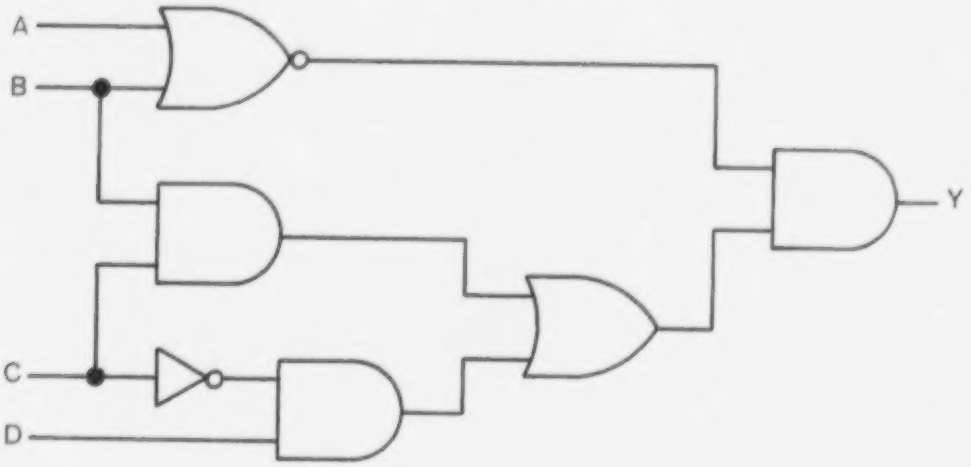


Assignment Sheet 11

7. ____________________

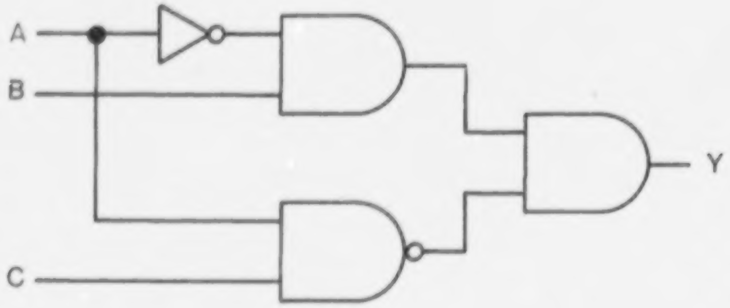


8. ____________________

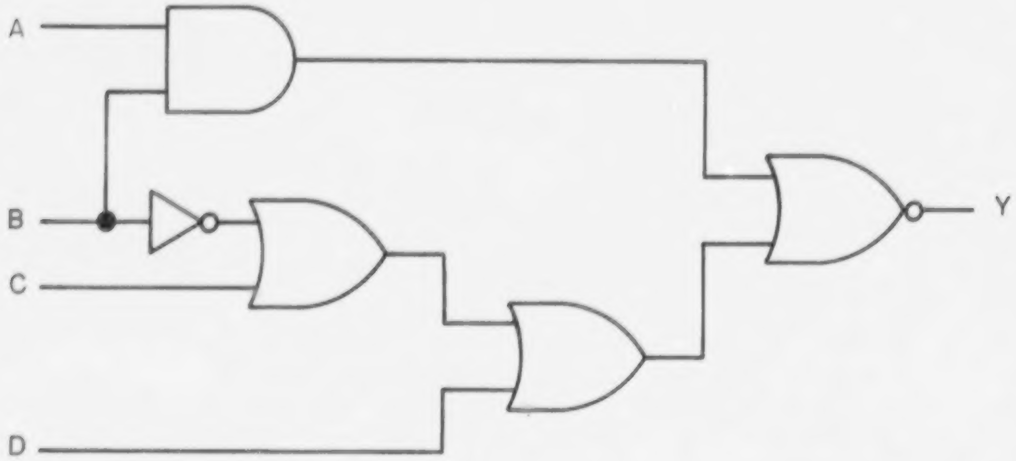


Assignment Sheet 11

9 ____________________



10. ____________________



Logic Devices and Circuits
Unit 1

Job Sheet 1—Construct and Test an "AND" Gate Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	Rating
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: Logic devices play specific roles in circuits and are helpful tools because of the way they shape signals. Therefore, it is important for the technician to understand how the signal is supposed to appear after the inputs have been combined in a logic device. In this and the next several job sheets you will work with different types of logic gates to gain further knowledge of how these devices operate.

Logic devices are available as discrete components but are more often used in IC packages, in which a number of logic gates and other devices are likely to be combined. In this way an IC can serve more than one circuit with different gates being active in the various circuits. For example, the IC recommended for this job sheet contains three AND gates, but the circuit that you will construct and test uses only one of them.

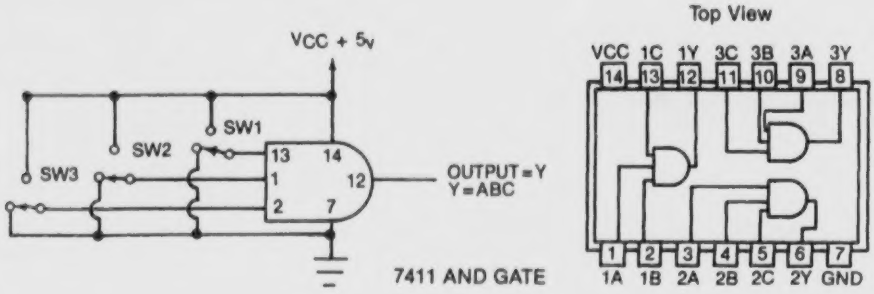
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Test leads
- DC power supply, 5 volt
- SN7411 triple three-input positive AND gates, or equivalent
- Three SPDT switches
- LED (optional)
- 470 ohm resistor (optional)
- Low-voltage conductor
- Mounting surface and hardware

Job Sheet 1

- Pencil and paper
- Table at end of job sheet
- Circuit drawing



B. Procedure

☐ 1. Assemble the circuit per the drawing, but do **not** apply power.

Note: Be sure to position the switches as shown.

☐ 2. Connect the multimeter to the output of the gate.

Note: You can add a visual indicator to the circuit by placing an LED and a series resistor between the gate output and ground, with the LED's cathode connected to ground. Discuss this option with your instructor at the next step.

☐ 3. Have your instructor check your circuit.

☐ 4. Energize the circuit.

☐ 5. Measure and record the output voltage as logic high (1) or logic low (0) in the table.

☐ 6. Change one switch position.

☐ 7. Measure and record the output voltage for the new configuration.

☐ 8. Repeat Steps 6 and 7 for each possible switch configuration.

☐ 9. Remove power from the circuit.

☐ 10. Discuss your results with your instructor.

Job Sheet 1

☐ 11. Disassemble the circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

____

____

____

Job Sheet 1

Data Table

SW-1	SW-2	SW-3	Expected Y Output	Actual Y Output
0	0	0		
0	0	1		
0	1	0		
1	0	0		
0	1	1		
1	1	0		
1	0	1		
1	1	1		

Logic Devices and Circuits
Unit 1

Job Sheet 2— Construct and Test an "OR" Gate Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	Rating
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

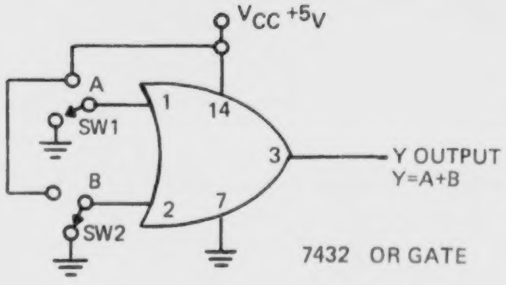
Introduction: With an OR gate, any logic high input will produce a high output. It does not matter whether there are two inputs with both being high or twenty inputs with one logic high, the output will be high. This is a valuable tool for causing a switch change or other circuit actions with a single input change. In this job sheet, you will construct and test a circuit using an OR gate.

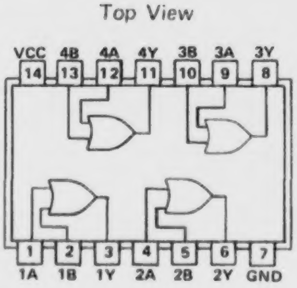
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Test leads
- DC power supply, 5 volt
- SN7432 quadruple two-input positive OR gates, or equivalent
- Two SPDT switches
- LED (optional)
- 470 ohm resistor (optional)
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing on the next page

Job Sheet 2





B. Procedure

☐ 1. Assemble the circuit per the drawing, but do **not** apply power.

Note: Be sure to position the switches as shown.

☐ 2. Connect the multimeter to the output of the gate.

Note: You can add a visual indicator to the circuit by placing an LED and a series resistor between the gate output and ground, with the LED's cathode connected to ground. Discuss this option with your instructor at the next step.

☐ 3. Have your instructor check your circuit.

☐ 4. Energize the circuit.

☐ 5. Measure and record the output voltage as logic high (1) or logic low (0) in the table.

☐ 6. Change one switch position.

☐ 7. Measure and record the output voltage for the new configuration.

☐ 8. Repeat Steps 6 and 7 for each possible switch configuration.

☐ 9. Remove power from the circuit.

☐ 10. Discuss your results with your instructor.

☐ 11. Disassemble the circuit and return equipment and materials to their proper storage location.

Job Sheet 2

Evaluator's comments: ____

____

____

____

Job Sheet 2

Data Table

SW-1	SW-2	Expected Y Output	Actual Y Output
0	0		
0	1		
1	0		
1	1		

Logic Devices and Circuits
Unit 1

Job Sheet 3— Construct and Test a "NAND" Gate Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

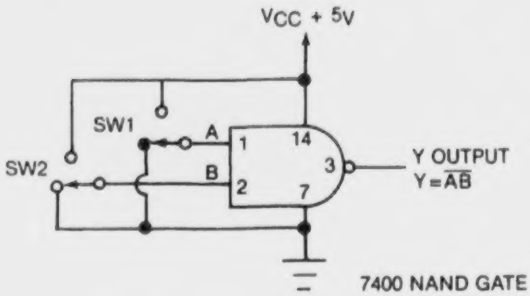
Introduction: In this job sheet you will use a NAND gate or, as recommended, an IC with four NAND gates, though only one will be used. You will use a two-input circuit similar to the one used with the OR gate. How do you expect the outputs to compare between the NAND and the OR gate circuits?

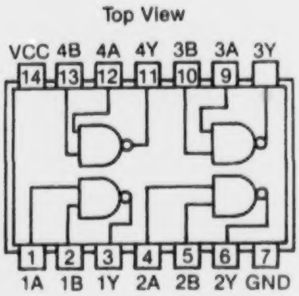
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Test leads
- DC power supply, 5 volt
- SN7400 quadruple two-input positive NAND gates, or equivalent
- Two SPDT switches
- LED (optional)
- 470 ohm resistor (optional)
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing on the next page

Job Sheet 3





B. Procedure

☐ 1. Assemble the circuit per the drawing, but do **not** apply power.

Note: Be sure to position the switches as shown.

☐ 2. Connect the multimeter to the output of the gate.

Note: You can add a visual indicator to the circuit by placing an LED and a series resistor between the gate output and ground, with the LED's cathode connected to ground. Discuss this option with your instructor at the next step.

☐ 3. Have your instructor check your circuit.

☐ 4. Energize the circuit.

☐ 5. Measure and record the output voltage as logic high (1) or logic low (0) in the table.

☐ 6. Change one switch position.

☐ 7. Measure and record the output voltage for the new configuration.

☐ 8. Repeat Steps 6 and 7 for each possible switch configuration.

☐ 9. Remove power from the circuit.

☐ 10. Discuss your results with your instructor.

☐ 11. Disassemble the circuit and return equipment and materials to their proper storage location.

Job Sheet 3

Evaluator's comments: ______________________________

Job Sheet 3

Data Table

SW-1	SW-2	Expected Y Output	Actual Y Output
0	0		
0	1		
1	0		
1	1		

Logic Devices and Circuits
Unit 1

Job Sheet 4— Construct and Test a "NOR" Gate Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	Rating
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

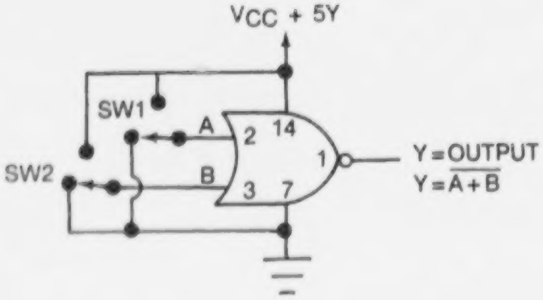
Introduction: This job sheet calls for use of a two-input NOR gate IC, with one gate active. Again, begin by considering how the output of this circuit will compare with the previous logic gate circuits that you have tested.

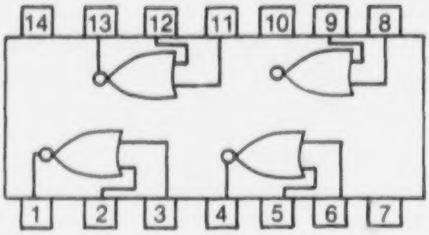
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Test leads
- DC power supply, 5 volt
- SN7402 quadruple two-input positive NOR gates, or equivalent
- Two SPDT switches
- LED (optional)
- 470 ohm resistor (optional)
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing on next page

Job Sheet 4





B. Procedure

☐ 1. Assemble the circuit per the drawing, but do **not** apply power.

Note: Be sure to position the switches as shown.

☐ 2. Connect the multimeter to the output of the gate.

Note: You can add a visual indicator to the circuit by placing an LED and a series resistor between the gate output and ground, with the LED's cathode connected to ground. Discuss this option with your instructor at the next step.

☐ 3. Have your instructor check your circuit.

☐ 4. Energize the circuit.

☐ 5. Measure and record the output voltage as logic high (1) or logic low (0) in the table.

☐ 6. Change one switch position.

☐ 7. Measure and record the output voltage for the new configuration.

☐ 8. Repeat Steps 6 and 7 for each possible switch configuration.

☐ 9. Remove power from the circuit.

☐ 10. Discuss your results with your instructor.

☐ 11. Disassemble the circuit and return equipment and materials to their proper storage location.

Job Sheet 4

Evaluator's comments: ______________________________

Job Sheet 4

Data Table

SW-1	SW-2	Expected Y Output	Actual Y Output
0	0		
0	1		
1	0		
1	1		

Logic Devices and Circuits
Unit 1

Job Sheet 5— Construct and Test an "Exclusive-OR" Gate Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	Rating
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

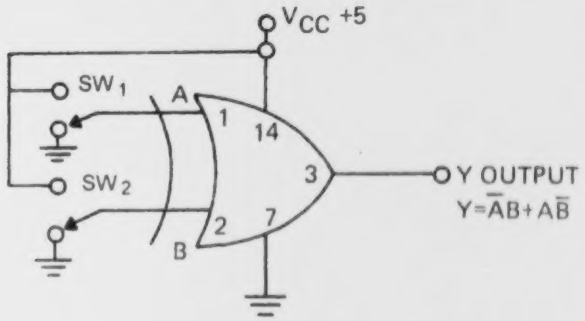
Introduction: This is the last job sheet in this series on building and testing logic gate circuits. As you prepare for this task, consider the results you observed with the previous logic gate circuits. Were the results as you expected and why or why not? What effect, if any, will your previous work with such devices have on this job sheet? How do you expect the exclusive-OR gate to be similar to the other logic gates and how do you expect it to be different?

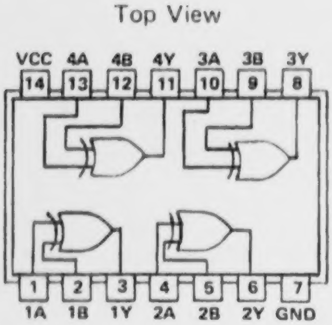
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Test leads
- DC power supply, 5 volt
- SN7485 quadruple two-input positive XOR gates, or equivalent
- Two SPDT switches
- LED (optional)
- 470 ohm resistor (optional)
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing on next page

Job Sheet 5





B. Procedure

☐ 1. Assemble the circuit per the drawing, but do **not** apply power.

Note: Be sure to position the switches as shown.

☐ 2. Connect the multimeter to the output of the gate.

Note: You can add a visual indicator to the circuit by placing an LED and a series resistor between the gate output and ground, with the LED's cathode connected to ground. Discuss this option with your instructor at the next step.

☐ 3. Have your instructor check your circuit.

☐ 4. Energize the circuit.

☐ 5. Measure and record the output voltage as logic high (1) or logic low (0) in the table.

☐ 6. Change one switch position.

☐ 7. Measure and record the output voltage for the new configuration.

☐ 8. Repeat Steps 6 and 7 for each possible switch configuration.

☐ 9. Remove power from the circuit.

☐ 10. Discuss your results with your instructor.

☐ 11. Disassemble the circuit and return equipment and materials to their proper storage location.

Job Sheet 5

Evaluator's comments: ______________________________

Job Sheet 5

Data Table

SW-1	SW-2	Expected Y Output	Actual Y Output
0	0		
0	1		
1	0		
1	1		

Logic Devices and Circuits
Unit 1

Job Sheet 6— Construct and Test a Four-Bit Shift Register

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	Rating
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: In this unit, you have studied how shift registers are used to move information from location to location and how they can be constructed from cascaded flip-flops. In this job sheet, you will construct a shift register using four J-K flip-flops, a configuration often used for shift registers. Data is transferred through this circuit one bit at a time.

You will also operate the circuit to ensure that it operates correctly. In preparation for this task, study data book entries about the ICs that you will use.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

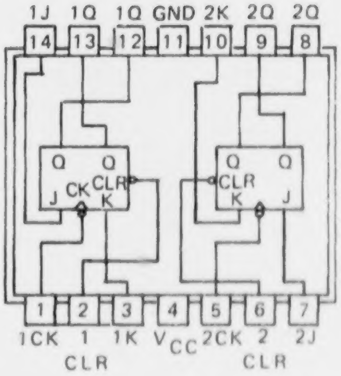
- Multimeter
- Function generator, or equivalent to produce square wave pulse with single-step capability
- Test leads
- DC power supply, 5 volt
- SN7404 hex inverter, or equivalent
- Two SN7473 dual J-K flip-flops
- Four SPDT switches
- Four LEDs
- Four 470 ohm resistors
- Low-voltage conductor
- Mounting surface and hardware

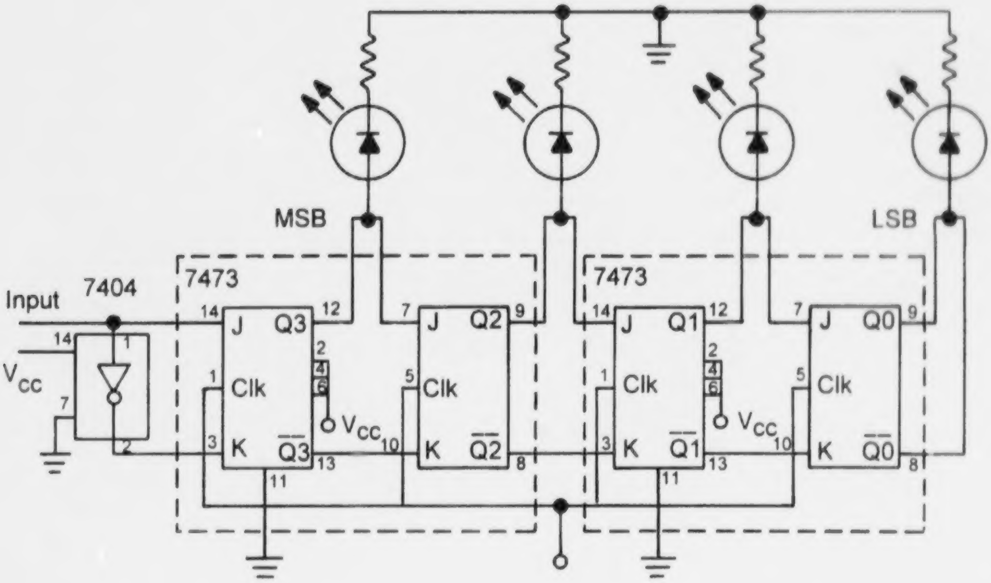
Job Sheet 6

- Pencil and paper
- Circuit drawing

'73,'H73,'L73
FUNCTION TABLE

INPUTS				OUTPUTS	
CLEAR	CLOCK	J	K	Q	$\overline{Q}$
L	X	X	X	L	H
H	⎍	L	L	Q_0	$\overline{Q}_0$
H	⎍	H	L	H	L
H	⎍	L	H	L	H
H	⎍	H	H	TOGGLE	





B. Procedure

☐ 1. Assemble circuit per drawing, but do **not** apply power.

☐ 2. Have your instructor check your circuit.

Note: Complete the next two steps as your instructor continues to observe.

Job Sheet 6

☐ 3. Energize the circuit at +5 VDC.

☐ 4. Ensure that each flip-flop is zeroed by momentarily grounding the CLEAR pin for any output that is high.

☐ 5. Place a logic high on the input terminal by connecting the terminal to the power supply.

☐ 6. Push the *shift pulse switch* or *clock pulse switch* one time.

☐ 7. Observe the LEDs.

Note: For each flip-flop outputting a logic high signal, the LED should be illuminated. For each flip-flop outputting a logic low signal, the LED should be out.

☐ 8. Record the output (0 or 1) for each flip-flop for this input.

☐ 9. Repeat Steps 5 through 8 to insert the binary number 1011, inserting a logic high or logic low signal as required.

Note: Switch the input to ground to produce a logic low input.

☐ 10. Remove power from the circuit.

☐ 11. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the purpose of the inverter in the circuit?
- What is the purpose of resetting the flip-flops before transmitting the binary number?
- How does grounding the CLEAR pin reset the flip-flop?
- How does grounding the power source result in the transmission of a logic low signal?
- What is the status of each flip-flop's output after each input signal? Does this show transmission of the data word 1011? How?

☐ 12. Disassemble circuit and return equipment and materials to their proper storage location.

Job Sheet 6

Evaluator's comments: ____

____

____

____

Logic Devices and Circuits
Unit 1

Job Sheet 7— Construct and Test a Flip-Flop Circuit

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	______
• Circuit was wired correctly	______
• Equipment was used correctly	______
• Measurements were accurate	______
• Student demonstrated an understanding of the applicable principles	______

Introduction: In this job sheet, you will use a logic probe and logic pulser to verify operation of a J-K flip-flop circuit. The two devices are likely to be similar in appearance and construction. However, they serve different purposes. The logic pulser is used to inject signals in a logic circuit, while the logic probe simply checks for the presence of a signal and often indicates whether the signal is high, low, or changing states. Care must be taken in using both devices to ensure that you are on the correct point in the circuit (such as an IC pin), that you make good contact, and that you do not cause damage through excessive pressure, bridging across circuits, puncturing insulators, etc. Make sure that your instructor has reviewed your use of logic probes and logic pulsers prior to beginning this procedure.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Oscilloscope
- Function generator
- Logic pulser
- Logic probe
- Test leads
- DC power supply, 5 volt
- SN7476 J-K flip-flop, or equivalent
- Pin out diagram for the flip-flop
- 4.7 Kohm resistor, ¼-watt

Job Sheet 7

- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper

B. Procedure

☐ 1. Connect the CLOCK pin to the resistor.

☐ 2. Connect the resistor to V_{CC}.

☐ 3. Energize the circuit at +5 VDC.

☐ 4. Connect the CLEAR to low and the SET to high.

☐ 5. Use the logic probe to check the output of Q and record its status.

☐ 6. Connect the CLEAR to low and the SET to low.

☐ 7. Use the logic probe to check the output of Q and $\overline{Q}$ and record its status.

☐ 8. Connect the CLEAR to high and the SET to high.

☐ 9. Use the logic probe to check the output of Q and record its status.

☐ 10. Set J to low and K to low.

☐ 11. Inject a pulse and then several pulses on the CLOCK pin with the logic pulser.

☐ 12. Measure and record Q.

☐ 13. Measure and record $\overline{Q}$.

☐ 14. Set J to low and K to high.

☐ 15. Inject a pulse and then several pulses on the CLOCK pin with the logic pulser.

☐ 16. Measure and record Q.

☐ 17. Measure and record $\overline{Q}$.

☐ 18. Set J to high and K to low.

☐ 19. Inject a pulse and then several pulses on the CLOCK pin with the logic pulser.

Job Sheet 7

☐ 20. Observe Q and record a description of its behavior.

☐ 21. Set J to high and K to high.

☐ 22. Inject a pulse and then several pulses on the CLOCK pin with the logic pulser.

☐ 23. Observe Q and record a description of its behavior.

☐ 24. Remove the input to the CLOCK terminal.

☐ 25. Connect a pulse input line from the function generator to the CLOCK terminal.

☐ 26. Use the oscilloscope to monitor the CLOCK and Q output.

☐ 27. Observe the two traces on the oscilloscope for approximately one minute and record your observations.

☐ 28. Discuss your results with your instructor; be prepared to discuss the following points:

- What happened to the Q output at Step 5? Step 7? Are these the expected results? Why or why not?
- At Step 6, with both CLEAR and SET low, an illegal state is indicated for both Q and $\overline{Q}$ high. What happened to the outputs at this step?
- What happens to control of the circuit once the CLEAR and SET both go high (Step 8)?
- When pulses are injected on the CLOCK pin, what is the effect on the two outputs?
- What is the effect of using the function generator on the CLOCK circuit?

☐ 29. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ____

____

____

____

Logic Devices and Circuits
Unit 1

Job Sheet 8— Construct and Test a J-K Counter Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: Flip-flops can also be used for counter circuits. The counters may be synchronous or asynchronous, depending on how the flip-flops are interconnected. In this job sheet you will construct and test a counter in each configuration.

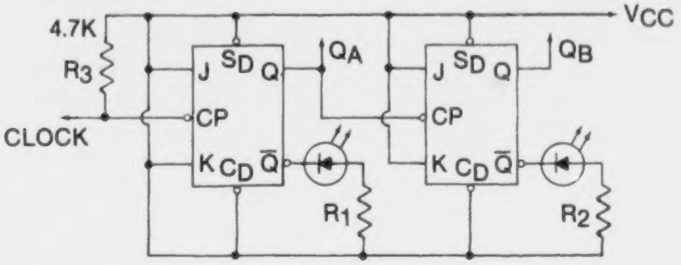
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

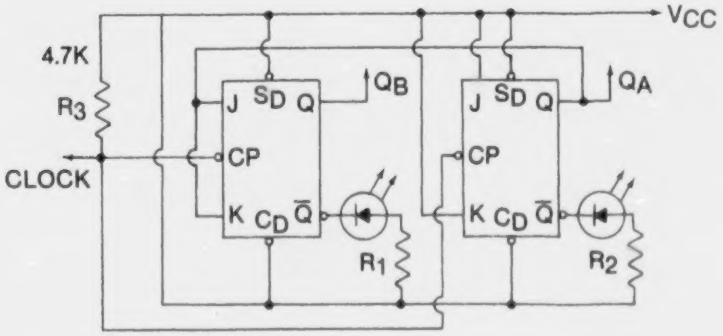
- Oscilloscope
- Function generator, square wave
- Test leads
- DC power supply, 5 volt
- Logic pulser
- Logic probe
- SN7476 J-K flip-flop, or equivalent
- Two LEDs
- Two 270 ohm resistors, ¼- watt
- 4.7 Kohm resistor
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Circuit drawings on the next page

Job Sheet 8

Circuit drawing 1



Circuit drawing 2



B. Procedure

☐ 1. Assemble circuit per drawing 1, but do **not** apply power.

☐ 2. Energize the circuit and adjust the power supply to 5 volts.

☐ 3. Using the logic pulser, inject signals on the CLOCK input.

☐ 4. Observe the LEDs and record the count sequence as you inject signals.

☐ 5. Remove power from the circuit.

☐ 6. Remove R_3 at the CLOCK connection.

☐ 7. Connect the function generator the CLOCK connection and set for a square wave of approximately 100 Hz.

Job Sheet 8

☐ 8. Energize the circuit.

☐ 9. Use the oscilloscope to measure the Q_A and Q_B waveforms.

☐ 10. Sketch the waveforms for the function generator and the two outputs.

☐ 11. Remove power from the circuit.

☐ 12. Assemble the circuit per drawing 2, but do **not** apply power.

☐ 13. Energize the circuit.

☐ 14. Repeat Steps 3-11 for the new configuration.

☐ 15. Discuss the results with your instructor; be prepared to discuss the following points:

- What function does each element in Circuit 1 serve?
- What function does each element in Circuit 2 serve?
- Which circuit is synchronous and which is asynchronous?
- What is the purpose of R_3 in each circuit and the effect of disconnecting it?

☐ 16. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ____

____

____

____

Logic Devices and Circuits
Unit 1

Job Sheet 9— Construct and Test an A/D Converter

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: Most electronic equipment generates and manipulates digital signals, even though the equipment may be connected to systems that provide analog inputs. For this reason, the equipment must possess a means of converting analog values to digital values. This is commonly done through the use of integrated circuits specifically designed to perform this task or which make the A/D conversion as a part of their other functions. In this job sheet, you will build an analog-to-digital converter and test its operation.

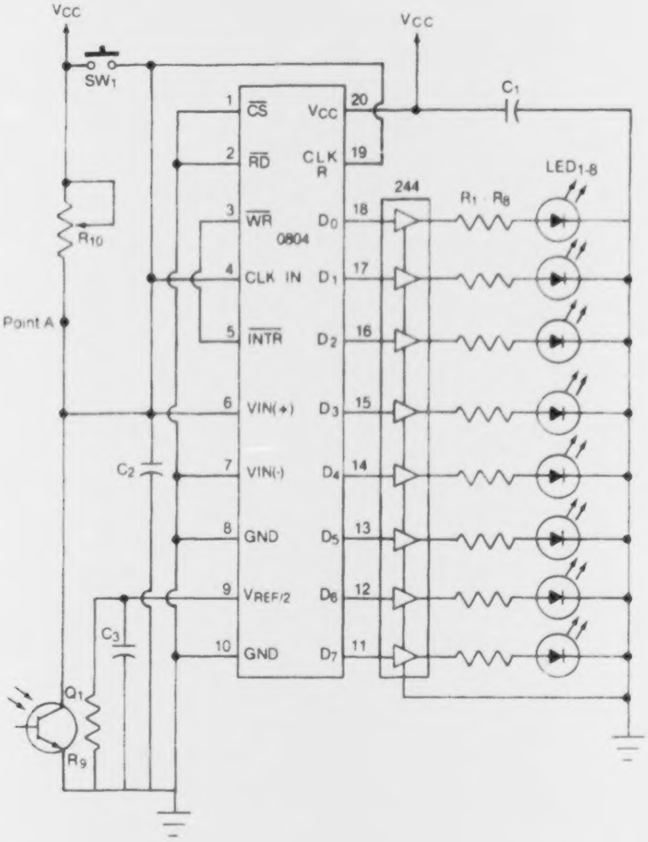
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter or voltmeter
- Test leads
- Power source
- ADC 0804 A/D converter IC
- 74LS244 octal buffer
- Phototransistor (Q_1)
- Normally open switch (SW_1)
- Eight LEDs
- 4.7 Kohm resistor (R_9)
- Eight 270-ohm resistors
- 100 Kohm potentiometer (R_{10})
- 22 mF tantalum capacitor (C_1)
- Two 0.1 mF capacitors

Job Sheet 9

- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of assignment sheet
- Circuit drawing



B. Procedure

☐ 1. Assemble the circuit per the drawing but do **not** apply power.

☐ 2. Energize the circuit.

☐ 3. Monitor the analog voltage at Point A.

☐ 4. Adjust R_{10} so that the voltage at Point A is 1 volt with full light striking the light-sensitive device.

Job Sheet 9

☐ 5. Momentarily close SW_1.

☐ 6. Adjust the light level to obtain various analog voltages.

☐ 7. Observe and record the digital voltage for each analog voltage.

Note: Record at least five analog voltages and observe and record the corresponding digital outputs.

☐ 8. Remove power from the circuit.

☐ 9. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the function of each element of the circuit?
- What is the effect on both the analog and digital signals of increasing the light intensity?
- Is there a clear mathematical relationship between the analog changes and the digital changes? For example, if the analog voltage doubles, does the digital output double?
- Explain how a useful digital device could be designed that converts light to analog current and then to digital output signals.

☐ 10. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

____

____

____

Job Sheet 9

Data Table

Voltage at Point A	Digital Output

Notes:

Logic Devices and Circuits
Unit 1

Job Sheet 10— Construct and Test a D/A Converter

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	______
• Circuit was wired correctly	______
• Equipment was used correctly	______
• Measurements were accurate	______
• Student demonstrated an understanding of the applicable principles	______

Introduction: Just as electronic circuits are often called upon to convert analog signals into digital signals, conversions in the other direction are also required. In this job sheet, you will construct a resistor network and measure its analog voltages in various circuit combinations. You will then attempt to duplicate those voltages after a digital conversion.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

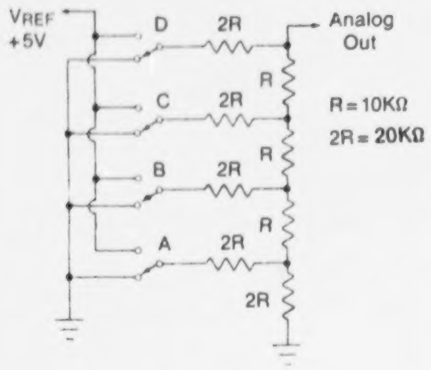
A. Equipment and materials

- Multimeter or voltmeter
- Logic pulser
- Function generator
- Test leads
- DC power supply, 5 volt
- SN7490 decade counter, or equivalent
- SN7448 BCD to seven-segment decoder, or equivalent
- 74LS244 octal buffer, or equivalent
- Four SPDT switches or jumper wires
- Common-cathode seven-segment display
- 4.7 Kohm resistor
- Three 10 Kohm resistors, ¼-watt
- Five 20 Kohm resistors, ¼-watt
- Low-voltage conductor
- Mounting surface and hardware

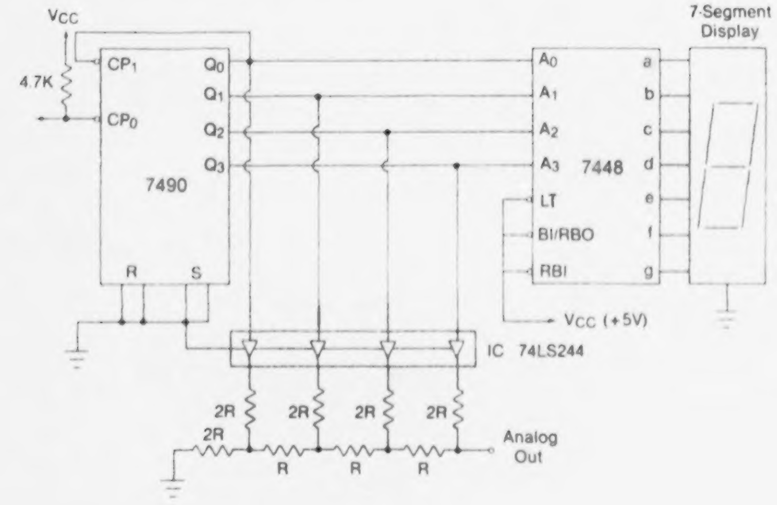
Job Sheet 10

- Pencil and paper
- Table at end of job sheet
- Circuit drawings

Circuit drawing 1



Circuit drawing 2



B. Procedure

☐ 1. Assemble circuit per Circuit Drawing 1, but do **not** apply power.

☐ 2. Position the switches so that each is connected to ground.

Job Sheet 10

☐ 3. Connect the multimeter to measure analog output.

☐ 4. Energize the circuit.

☐ 5. Record the analog output in the table under **Circuit 1**.

☐ 6. Reposition Switch A to V_{CC}.

☐ 7. Record the analog output in the table under **Circuit 1**.

☐ 8. Repeat Steps 6 and 7 for each switch setting listed on the table.

☐ 9. Remove power from the circuit.

☐ 10. Assemble the circuit shown in Circuit Drawing 2 to include the resistor network portion of Circuit 1; do **not** apply power.

☐ 11. Have your instructor check your circuit and observe your performance of the next three steps.

☐ 12. Connect the multimeter to the analog output.

☐ 13. Energize the circuit.

☐ 14. Use the logic pulser to step the decade counter through its count (0-9) and read the analog output voltage values.

☐ 15. Connect the counter CP line to a 100 Hz square wave.

☐ 16. With an oscilloscope triggered by the CP input, observe and sketch the waveforms of the CP input and the analog output.

☐ 17. Remove power from the circuit.

☐ 18. Discuss your results with your instructor; be prepared to discuss the following points:

- What were the differences, if any, between the outputs of the two circuits? If a difference was observed, what would cause the difference?
- How does the ladder circuit function?
- What is the role of each component in Circuit 2?
- How do the switch settings in the chart relate to a logic table?

☐ 19. Disassemble circuit and return equipment and materials to their proper storage location.

Job Sheet 10

Evaluator's comments:

Job Sheet 10

Data Table

Switch Settings					Analog Output	
Display	A	B	C	D	Circuit 1	Circuit 2
0	GND	GND	GND	GND		
1	GND	GND	GND	V_{CC}		
2	GND	GND	V_{CC}	GND		
3	GND	V_{CC}	V_{CC}	V_{CC}		
4	GND	V_{CC}	GND	GND		
5	GND	V_{CC}	GND	V_{CC}		
6	GND	V_{CC}	V_{CC}	GND		
7	GND	V_{CC}	V_{CC}	V_{CC}		
8	V_{CC}	GND	GND	GND		
9	V_{CC}	GND	GND	V_{CC}		

Logic Devices and Circuits
Unit 1

Job Sheet 11—Construct and Test a BCD to Seven-Segment Decoder

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Circuit was wired correctly	________
• Equipment was used correctly	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

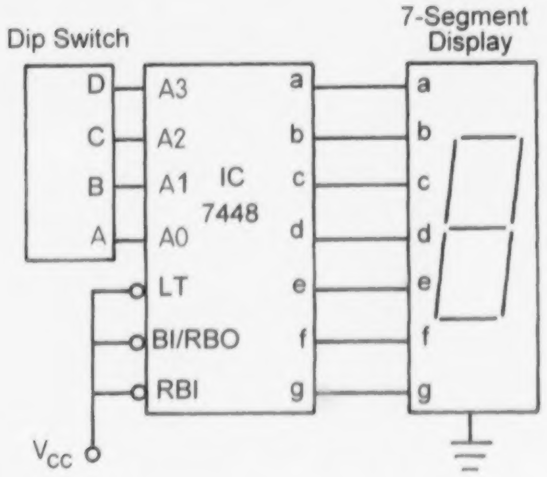
Introduction: Electronic equipment often uses displays to provide information to the operator, from an LED showing the track being played on a CD to a complex computer graphic on a 17-inch monitor. For the most part, these displays work by using an electrical current to illuminate light patterns that represent information. The control of the lights may be through hardware, software, or a combination of the two. In this job sheet, you will build and test a circuit that provides a light display in response to a binary input.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Power supply
- SN7448 BCD to seven-segment decoder, or equivalent
- 74LS244 octal buffer, or equivalent
- DIP switch
- Common-cathode seven-segment display
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Circuit drawing on next page

Job Sheet 11



B. Procedure

☐ 1. Assemble circuit per drawing, but do **not** apply power.

☐ 2. Energize the circuit.

☐ 3. Set the DIP switch to display 0 and note the switch readings.

☐ 4. Repeat Step 3 for the remaining digits shown by the display.

☐ 5. Ask your instructor to prepare a simulated problem by removing the power to one switch.

☐ 6. Describe for your instructor a procedure for determining which line is defective.

☐ 7. Perform the troubleshooting procedure to isolate the problem.

☐ 8. Remove power and repair the disconnected line.

☐ 9. Repeat Steps 1-3 to verify operation of the circuit.

☐ 10. Remove power from the circuit.

☐ 11. Discuss your results with your instructor.

☐ 12. Disassemble circuit and return equipment and materials to their proper storage location.

Job Sheet 11

Evaluator's comments: ____

____

____

____

Logic Devices and Circuits
Unit 1

Job Sheet 12—Troubleshoot Logic Circuits

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	Rating
• Troubleshooting procedure was well designed	________
• Equipment was used correctly	________
• Correct problems were identified	________
• Problems were correctly repaired	________

Introduction: For this job sheet, your instructor will provide you with a logic device or circuit that has one or more problems. Those problems may be defective components, shorts, opens, incorrect wiring, and other problems that an electronics technician is likely to encounter in this type of circuit. Using what you have learned about troubleshooting, component testing, and logic device operation, you will be required to design a troubleshooting procedure for the circuit and then carry out that procedure to identify and correct problems in the circuit.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Logic device or circuit provided by instructor
- Paper and pencil
- Equipment as required by troubleshooting procedure
- Materials as required by troubleshooting procedure

B. Procedure

☐ 1. Examine device for preliminary troubleshooting assessment.

☐ 2. Define troubleshooting procedure in writing.

☐ 3. Discuss troubleshooting procedure with instructor.

☐ 4. Conduct troubleshooting procedure.

Job Sheet 12

☐ 5. Identify problems and record results of troubleshooting.
☐ 6. Repair equipment to return to operational state.
☐ 7. Verify that repair has returned equipment to an operational state.
☐ 8. Discuss the problem and your response with your instructor.
☐ 9. Return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

____

____

____

Introduction to Microprocessors
Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss the design and operation of microprocessors and be able to check the operation of microprocessor circuits. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms associated with microprocessors to their correct definitions.
2. Label the parts of a computer block diagram.
3. Match the sections of a computer to their correct descriptions.
4. State the purpose of the two major sections of the central processing unit.
5. Match functional areas of the CPU register section to their correct descriptions.
6. Describe the three ways in which information flows through a microprocessor.
7. Complete statements about the flow of information through a microprocessor.
8. Match types of memory devices to their correct descriptions.
9. List types of bus construction.
10. Complete statements about the system bus.
11. Complete statements about data busses.
12. Complete statements about address busses.
13. Complete statements about control busses.
14. Complete statements about clock timing in a microprocessor.
15. Explain the purpose and operation of an interrupt.
16. Complete statements about computer operation.

Objective Sheet

17. Distinguish between the use and functioning of machine and assembler languages.

18. Distinguish among characteristics of various communications standards.

19. State the two major purposes of a computer operating system.

20. Match types of computer peripherals to their correct descriptions.

21. Write and run a machine language driver program to check read/write memory location. (Job Sheet 1)

22. Use a digital voltmeter to test supply voltages on a microcomputer system bus. (Job Sheet 2)

23. Use an oscilloscope to check a computer clock system. (Job Sheet 3)

24. Set up and configure a personal computer. (Job Sheet 4)

25. Troubleshoot microprocessor circuits. (Job Sheet 5)

Introduction to Microprocessors
Unit 2

Information Sheet

1. **Terms and definitions**

   a. **Address word**—String of symbols such as binary bits used to indicate the memory location of data or an input/output device

   b. **Bus**—Conductive path within a computer over which instructions and data are transmitted

   Examples: Wires, printed circuit boards, silicon paths

   c. **Computer**—Electronic device that, upon the receipt of instructions, can perform calculations on numerical information and can store and correlate other forms of information, such as words, images, and digitized sound

   Examples: Notebook, laptop, personal, workstation, mainframe, super computers

   d. **Data word**—String of symbols such as binary bits used to represent information other than instructions in computer operations

   e. **Firmware**—Hardware that contains embedded software

   Examples: Erasable programmable read-only memory, programmable logic device

   f. **Hardware**—The physical components of a computer system

   g. **Interface**—Point of connection between two devices or the hardware or software that provides that interconnection

   h. **Interrupt**—Signal sent by a computer-internal device requesting service from the microprocessor

   i. **Language**—Any of various systems for representing data, instructions, and operational information for use by a computer

   Examples: Machine language, assembler language, COBOL, FORTRAN, BASIC

   j. **Memory**—Area of computer or other programmable device in which information can be stored either temporarily or until deleted or changed

Information Sheet

k. **Operating system**—Format for the master control program of a computer that is permanently stored in memory and that interprets commands so that devices and programs can interface

Examples: MS-DOS, Windows, Macintosh OS, OS/2, UNIX, VAX

l. **Peripheral**—Any device external to a computer that is electrically connected to the computer and which provides information to the computer or processes information from the computer

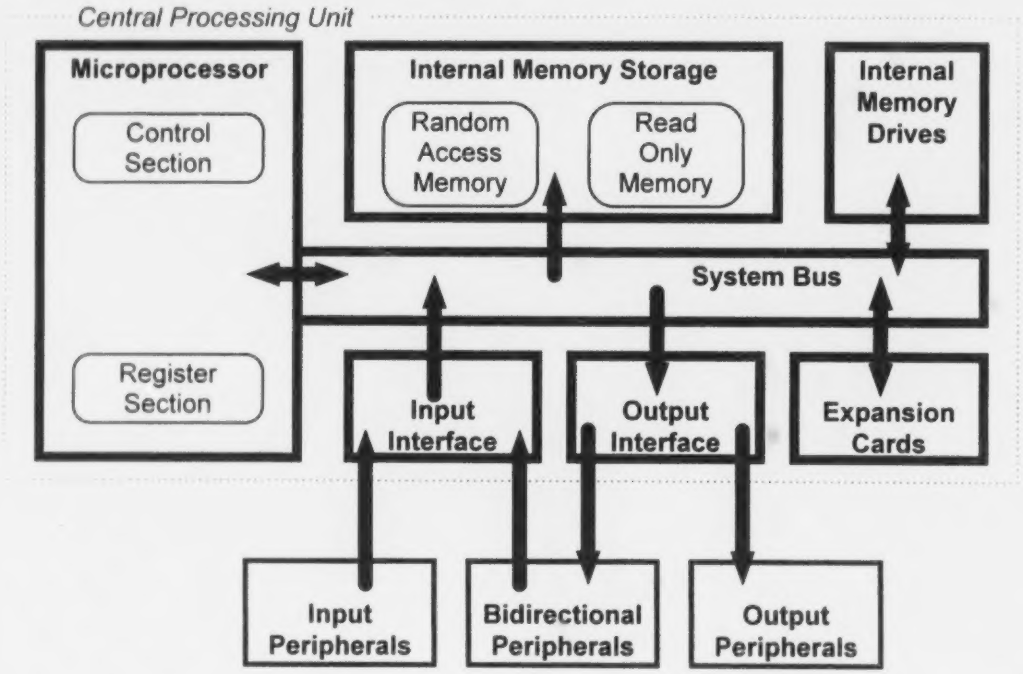
Examples: Keyboard, mouse, monitor, printer

m. **Program**—Detailed set of instructions that describe operations to be performed by a computer to accomplish specific tasks

n. **Protocol**—Communications exchange accomplished with software

o. **Software**—Electronically recorded programs stored in such a manner that they can be inserted into or removed from a computer

2. Parts of a computer block diagram



Information Sheet

3. Sections of a computer

a. Central processing unit (CPU)—Contains the arithmetic logic unit (ALU), control circuitry, some registers, and a program/address counter

Note: In most personal computers, sometimes called *microcomputers*, the CPU is contained on a single IC called the *microprocessor*. The microprocessor, much of the computer memory, several bus paths, and certain input/output devices reside on a circuit board that is commonly referred to as the *motherboard* or sometimes as the *parentboard*.

b. Memory section—Contains random access memory (RAM) and read-only memory (ROM), as well as magnetic memory for temporary or permanent storage of information

Note: In personal computers, the memory section usually includes ICs (such as single in-line memory modules [SIMMs] for RAM and board-mounted ROM ICs) and a device called a *hard disk drive* or *hard drive* that stores information magnetically.

c. Input/output (I/O) section—Contains circuitry to provide interfaces to peripheral devices and networks

Note: Computers use standardized connectors for I/O devices. For personal computers, some of the more common are the Small Computer Standard Interface (SCSI; pronounced *scuz-ee*), RS-232 serial interface, Centronics parallel interface, and PC-104 interface.

d. Busses—System wires or printed circuits used to connect the CPU to the remainder of the system

e. Registers—Internal devices where stored information is manipulated in data groups

4. Purposes of the two major sections of a central processing unit

a. Control section—Receives instructions from the data bus, decodes them, and processes clock timing and interrupt signals

b. Register section—Carries out operations, calculations, memory retrieval, and similar functions

Information Sheet

5. Functional areas of the CPU register

a. Arithmetic logic unit (ALU)—Performs calculations, sends information to the accumulator, and initiates the output to the flag register

b. Accumulator—Stores quantities to be operated on by the ALU and receives the results of the arithmetic operation performed by the ALU

c. Program counter—Controls the step-by-step progress of operations as the CPU executes a program

d. Index register—Increments and decrements through the memory contents to help accomplish a repetitive task

e. Stack pointer—Keeps track of where information is when memory stacking occurs and points the programmer to data storage locations

f. Flag register—Contains bits of data that indicate the status of the microprocessor at the end of the last instruction that was executed

6. Ways in which information flows through a microprocessor

a. Address word—Originates in the microprocessor and flows to the remaining parts of the system

b. Data word—Originates outside of the microprocessor, flows into the microprocessor, and out to the system

c. Control information—Flows in and out of the microprocessor

7. The flow of information through a microprocessor

a. To start information flow, an instruction word is sent to the microprocessor via the data line in the data bus.

b. The information contained in the instruction is a binary word from the data bus and is deposited in the instruction register.

c. The received instruction word will be latched into the instruction decode section of the microprocessor, where it is decoded.

Information Sheet

8. Types of memory devices

a. Read-only memory (ROM)—Nonvolatile data stored in an IC, compact disc, or computer hard drive; usually includes programming to control basic operations and such decoding functions as reading the keyboard and controlling video information for display

b. Erasable programmable read-only memory (EPROM)—Nonvolatile data stored in an IC or circuit that can be erased with ultraviolet light and reprogrammed

c. Electronically erasable programmable read-only memory (EEPROM)—Nonvolatile data stored in an IC or circuit that can be erased and reprogrammed electronically

d. Random access memory (RAM)—Volatile data storage that is easily written, read, and rewritten by the operator or computer

e. Static random access memory (SRAM)—Volatile data storage that retains its contents until altered or power is removed

f. Dynamic random-access memory (DRAM)—Volatile data storage that retains data for one or two milliseconds so that it must be continually refreshed if the data is to be retained

9. Types of bus construction

Note: Most microcomputer busses are parallel synchronous designs so that multiple signals can be transferred from one part of the system to another and arrive at the same time.

a. Silicon pathway

b. Printed circuit pathway

c. Wire conductor

10. System bus

a. Is generally designed to comply with a bus interface standard.

Examples: S-100, IEEE 488

b. Provides interface for adding expansion cards and other devices to change or enhance the computer's capabilities.

Information Sheet

11. Data bus

a. Is generally a multiconductor cable or PCB pathway.

b. Carries information in specific sized word groups in parallel to and from the microprocessor.

Examples: 8-bit, 16-bit, 32-bi, 64-bit

c. The word groups are synchronized by the system clock with bus operation being bi-directional.

d. The word groups may contain instructions, data, or address information.

12. Address bus

a. Is generally a multiconductor cable or PCB pathway.

b. Carries addresses generated by the microprocessor to designated devices.

Examples: RAM, ROM, I/O device

c. Information carried indicates location in RAM, ROM, or I/O device to which the data is being sent or from which the microprocessor may retrieve the information.

13. Control bus

a. May provide specialized functions specific to the system.

b. Controls timing and direction of information flow.

c. Signals tend to be less synchronized than on other busses.

d. Usually carries clock pulses, read/write signals, and interrupt signals.

14. Clock timing in a microprocessor

a. Timing may be an internal function of the microprocessor or provided through a separate clock circuit.

b. The clock pulse is usually a two-phase, nonoverlapping waveform created by starting two signals of the same frequency at slightly different times.

c. When one waveform is high, the other is low, allowing the signals to be identified as phase one (high) and phase two (low).

Information Sheet

d. The clock provides timing signals to all parts of the system and does not need to be addressed.

e. The CPU controls the system busses, and the clock controls timing to all of the system.

f. If the clock fails, the system is inoperative.

g. A high-speed timing cycle may be manipulated by an interrupt signal from the computer operator or from an external device.

15. Purpose and operation of an interrupt

a. An interrupt is a signal from a device that is requesting service by the microprocessor.

b. An interrupt will cause a microprocessor to stop what it is doing and perform some other operation for which it has been programmed.

c. Interrupts permit external asynchronous input into the microprocessor so that it may be used for multiple purposes.

16. Computer operation

a. Before a program may be executed, the program counter must be set to a memory location that begins the program.

b. The CPU places the contents of the program counter on the address bus.

c. The program counter proceeds to the next sequential memory location, where it stops until it receives instructions from the CPU decoder section.

d. The address bus selects the contents of the memory specified and places the instruction that it finds onto the data bus.

e. The data bus carries the data to the instruction register of the CPU.

f. The CPU decoder sets the appropriate registers in response to the instruction.

g. If additional data is required, the CPU will query the program counter for the required address on the system address bus to retrieve data from other memory addresses.

h. Once all the data has been received and the registers have been set, the CPU will execute the program.

Information Sheet

17. Use and functioning of machine versus assembler languages

a. Machine language

- Requires the computer operator to specify memory addresses in the computer and machine codes that are understood by the computer control section.
- Requires the use of data for operations in a suitable code, such as binary or hexadecimal.
- Requires the use of codes and addressing modes that are specifically suited for the computer's microprocessor.
- Language in which most system troubleshooting routines are written.
- Usually requires longer to create a program.
- Completed programs execute faster.

b. Assembler language

- Uses mnemonics, which are generally three- or four-letter codes that may be abbreviations for the operations they represent.

  Examples: ADC means *add with carry*, LDA means *load the accumulator*
- Addressing is done with labels rather than specific addresses.
- No allowance is necessary for specific microprocessors while writing the program.
- Once written, the program must be processed through an assembler to convert the program to a format that the computer will understand.
- Generally is easier and faster for the programmer.

Information Sheet

18. Communications standards

Note: Numerous computer application communications standards exist other than those listed here, such as IEEE-488 parallel bus, general purpose interface bus, and PC-104. These busses generally have specific applications or have yet to gain the popularity of the standards given here.

a. Serial

- Communications standard RS-232 as defined by the Electronics Industry Association is the accepted guideline for serial communications.
- Provides electrical parameters.
- Provides dimensions and pin assignments for a standard interface.
- Allows for prescribed exchange of predetermined signals upon initial connection between two devices (*handshaking*).
- Defines high- and low-bit signals used to mark the beginning and end of a transmitted word.

b. Centronics parallel

- Industry standard is Centronics for parallel communications.
- Commonly used to connect printers to computers.
- Provides electrical parameters.
- Provides dimensions and pin assignments for a standard interface.

c. SCSI parallel

- Uses hardware standard known as Small Computer System Interface.
- Supports up to eight devices.
- Has no formal driver standards.

  Note: *Driver* refers to software used to make the hardware interfaces between devices, such as printers and computers, work. There is not a single SCSI driver standard. However, Apple Computer began defining some standards for its equipment in the 1980s. In March 1990, IBM released SCSI driver standards that the company was incorporating into its equipment, and these have pretty much become the standards for IBM-compatible systems.

Information Sheet

19. **Purposes of a computing operating system**

    a. To control the allocation and usage of hardware, such as memory, the CPU, disk space, and peripherals

    b. To provide a standard interface for software applications, such as word-processing and spreadsheet programs

20. **Types of computer peripherals**

    a. Monitor—Output device that provides a visual representation of computer status and operations

    b. Keyboard/keypad—Input device that provides the operator with a means of transmitting symbols to the CPU using keys as on a calculator or typewriter

    c. Mouse—Input device that provides the operator with a means of selecting displayed choices of operations by moving a pointer

    Note: The pointer is usually a flashing line referred to as a *cursor* and may take other shapes such as arrows or cross hairs for different operations.

    d. Joystick—Input device that provides the operator limited input options for specialized programs such as interactive games

    e. Printer—Output device that can convert data stored in the computer to symbols printed on paper

    f. Memory drives—Input/output devices that can be used to supplement the computer memory, provide additional types of storage, or input data

    Examples: External hard drives, tape recorders, CD-ROMs, diskette drives

    g. Modem—Input/output device to allow the computer to interface with telephone lines

    h. Scanner—Input device that converts printed images into digital signals that can be processed by the computer

    i. Light pen—Input device for use on monitor screens that are sensitive to signals emitted by the pen

    j. Touch screen—Input device that is generally laid over the monitor screen to allow the operator to input commands by means of touching the screen

    Note: Touch screen sensitivity may be achieved in a number of ways, employing capacitive-resistive grids, infrared light beams, surface acoustic waves, and other designs.

Introduction to Microprocessors
Unit 2

Job Sheet 1— Write and Run a Machine Language Driver Program to Check Read/Write Memory Location

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
- Procedures were done correctly	________
- Equipment was operated correctly	________
- Program was correct and functioned properly	________
- Student demonstrated an understanding of the applicable principles	________

Introduction: Electronic technicians are often involved in the automated testing of electronic equipment and other activities that use simple computer routines to perform automated tasks. The technician who is familiar with the basics of developing such programs will better understand the processes involved and will often be called upon to develop those routines. In this job sheet, you will create a simple machine language program in order to acquaint you with the process.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Note: The exact process will vary with the type of processor used. The steps here provide a general procedure, but you will work with your instructor and the operator's manual for the computer being used to refine this procedure to fit your specific situation.

A. Equipment and materials

- Microcomputer
- Operator's manual for computer
- Pencil and paper

Job Sheet 1

B Procedure

☐ 1. Review operator's manual to determine procedures for starting and operating computer and for writing and loading machine language programs.

☐ 2. Turn on the computer and boot up the system as required.

☐ 3. Make keyboard entries necessary to prepare computer to perform machine language operations.

☐ 4. Perform steps necessary to prepare computer for machine language programming entries.

☐ 5. Make the following one-line entry in hexadecimal:

```
* 300 A9 00 85 00 C5 00 D0 0B A9 FF 85 00
```

Note: In some systems the asterisk (*) may appear automatically. Be sure to type the number *0* and not the letter *O*.

☐ 6. Press the ENTER key.

☐ 7. Make the second one-line entry in hexadecimal:

```
* 30C C5 00 D0 03 4C 69 FF 20 F0 FD E
```

☐ 8. Press the ENTER key.

☐ 9. Conclude the program by typing:

```
300L
```

☐ 10. Check your entries to see that they agree with what was supposed to have been typed.

☐ 11. Press the ENTER key to execute the program.

☐ 12. Verify the monitor display for the proper assembler language codes.

☐ 13. Write down the machine and assembler codes.

☐ 14. Exit the program and shutdown the system in accordance with the operator's manual.

☐ 15. Discuss your results with your instructor.

Job Sheet 1

☐ 16. Return equipment and materials to their proper storage location.

Evaluator's comments: ____________________

____

____

____

Introduction to Microprocessors
Unit 2

Job Sheet 2—Use a Digital Voltmeter to Test Supply Voltages on a Microcomputer System Bus

Name ____________________ Attempt Number __________

Date ____________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	______
• Equipment was operated correctly	______
• Expected values were correctly determined	______
• Measured values are correct	______
• Student demonstrated an understanding of the applicable principles	______

Introduction: A condition that is likely to cause problems with any piece of electronic equipment is bad supply power. The problem may be power without the right characteristics (current, voltage, etc.) or power that is too noisy (having too much ripple or interference, for example). The problem may occur at the source or at any point along the distribution system. In a computer, this can include any place along the computer's busses. In this job sheet, you will determine whether the system bus voltages in a microcomputer are correct.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Note: The exact process will vary with the type of computer used. The steps here provide a general procedure, but you will work with your instructor and the operator's manual for the computer being used to refine this procedure to fit your specific situation.

A. Equipment and materials

- Microcomputer
- Service manual for computer
- Extender card for system bus (if available)
- Digital voltmeter
- Test leads
- Pencil and paper

Job Sheet 2

B. Procedure

☐ 1. Determine voltage points on system bus and the specified value for each.

☐ 2. Remove the case cover from the computer.

☐ 3. Install the extender card, if used.

☐ 4. Power up the computer.

☐ 5. Set the voltmeter to measure DC voltage.

☐ 6. Measure and record the voltage at each test point.

Note: If the voltmeter being used does not adjust polarity automatically, be sure to set up the meter leads correctly for the polarity of each test point.

☐ 7. Turn off the voltmeter.

☐ 8. Shut down the computer.

☐ 9. Discuss your results with your instructor.

☐ 10. Restore the computer to its original configuration and return equipment and materials to their proper storage location.

Evaluator's comments: ____

____

____

____

Introduction to Microprocessors
Unit 2

Job Sheet 3— Use an Oscilloscope to Check a Computer Clock System

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	Rating
• Procedures were done correctly	______
• Equipment was operated correctly	______
• Expected values were correctly determined	______
• Measured values are correct	______
• Student demonstrated an understanding of the applicable principles	______

Introduction: As noted in the information sheet, a computer with an inoperative clock will not function. A computer with a clock system that fails to remain synchronized will not function correctly, if at all. Thus, computer service technicians and electronics technicians who maintain the computers with which they work must know how to verify clock operation as described in this job sheet.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Note: The exact process will vary with the type of computer used. The steps here provide a general procedure, but you will work with your instructor and the operator's manual for the computer being used to refine this procedure to fit your specific situation.

A. Equipment and materials

- Microcomputer
- Service manual for computer
- Extender card for system bus (if available)
- Dual-trace oscilloscope
- Test leads
- Pencil and paper
- Graph paper

Job Sheet 3

B. Procedure

☐ 1. Set up oscilloscope for operation.

☐ 2. Turn on oscilloscope and allow it to warm up as you proceed with the next few steps.

☐ 3. Remove the computer case cover as required.

☐ 4. Install the bus extender card, if used.

☐ 5. Determine clock test points on system bus or extender and the configuration of the oscilloscope leads to test the clock signals.

☐ 6. Locate the clock signal waveform diagram in the service manual.

☐ 7. Have your instructor check your setup and approve your planned procedure.

☐ 8. Once the oscilloscope is warmed up, set and adjust the intensity and focus for a sharp, clear trace.

☐ 9. Set for automatic sweep.

☐ 10. Position the Channel 1 trace two divisions above the center line on the oscilloscope display.

☐ 11. Position the Channel 2 trace two divisions below the center line on the oscilloscope display.

☐ 12. Touch the Channel 1 probe to the *01 position* of the clock system and ground the circuit.

☐ 13. Touch the Channel 2 probe to the *02 position* of the clock system.

Note: It is not necessary to ground the Channel 2 probe. However, the Channel 2 ground lead should not be allowed to touch other circuits and should be detached if possible.

☐ 14. Power up the computer and allow it to stabilize.

☐ 15. Adjust the oscilloscope traces to produce waveforms that are both approximately one graticule high.

☐ 16. Adjust the Channel 1 horizontal position so that the leading edge of the waveform crosses the zero line at the left edge of the display.

Job Sheet 3

☐ 17. Verify that the Channel 2 waveform moved in the opposite direction of the Channel 1 display as it was adjusted.

Note: If the Channel 2 trace did not move in the opposite direction, one or both of the waveforms may not be clock signals as there are other signals present on the system bus. If you cannot locate the clock signals, ask your instructor for assistance.

☐ 18. Sketch the waveforms on graph paper, showing their amplitude and frequency to scale.

☐ 19. Change the horizontal sweep frequency to one-half of its setting in Step 18.

☐ 20. Sketch the waveforms for the new setting.

☐ 21. Change the Channel 1 *volts per division* setting to the next lower division.

☐ 22. Observe the effect on the Channel 2 trace.

☐ 23. Change the Channel 2 *volts per division* setting to the next lower division.

☐ 24. Sketch the waveforms for the new setting.

☐ 25. Turn off the oscilloscope.

☐ 26. Shut down the computer.

☐ 27. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the relationship between the first and second clock signals and why are they set up this way?
- What happened to the waveforms when the horizontal sweep frequency was changed? Why?
- What happened when the *volts per division* setting was changed? Why?

☐ 28. Restore the computer to its original configuration and return equipment and materials to their proper storage location.

Job Sheet 3

Evaluator's comments: ____________________

____

____

____

DM-129

Introduction to Microprocessors
Unit 2

Job Sheet 4—Set Up and Configure a Personal Computer

Name ______________________ Attempt Number ____________

Date ______________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment operates correctly	________
• Software functions are correct	________
• Peripheral installations are correct	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: Personal computers are becoming virtually indispensable in the workplace, including electronics industry offices and shops. Many electronics technicians work with computers on a daily basis for tasks ranging from parts ordering and inventorying to on-line repair manuals to automated test procedures and virtually every other task. Add to this the role of the technician in building, selling, servicing, upgrading, and expanding computers, and it becomes obvious that the electronics technician must know how to operate a computer and, in most cases, must know how to set up and configure computers, whether they are the ones used by the technician on the job or those of others requiring setup or service. This job sheet covers many of the tasks associated with setting up and configuring a computer.

This job sheet is somewhat different from others with which you have worked. Because of the variety of computers that are available, the different software packages that can be loaded in them, the wide selection of peripherals, the number of possible configurations, and other factors, it is not possible to describe an exact procedure for accomplishing these tasks without specifying the hardware, software, and configuration. Such specification is not practical as it is unlikely that your facility would have the exact combination specified and the desire to repeat that process over and over for each student in your program. Besides, the way technicians set up and configure computers is by following operator's and service manuals—which is exactly what you will do in this job sheet.

As part of this effort, these are some of the tasks that you may be required to perform:

- Assemble basic hardware package, including CPU, monitor, keyboard, mouse, power cord, and interconnecting cords

Job Sheet 4

- Load system software
- Configure system software
- Load functional software programs, such as word processing, spread sheet, graphics, data base, and other programs
- Connect and configure peripherals, including printers, external hard drives, external tape drives, external modems, scanners, etc.
- Install internal hardware, such as disk drives, internal modems, sound and video cards, etc.
- Upgrade or expand parentboard by replacing microprocessor IC or adding additional memory
- Run a virus seeking program
- Run diagnostics programs

Your instructor will work with you to determine the tasks that you will demonstrate as part of this job sheet.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Microcomputer
- Operator's and service manual for computer
- Software for initial configuration
- Additional software to be loaded
- Manuals for software
- Peripherals to be installed
- Manuals for peripherals
- Hardware to be installed in computer
- Cables, connectors, and adapters as required for connections
- Basic hand tools required for installation
- Special tools as required for some procedures, such as IC insertion tools
- Pencil and paper

B. Procedure

As required for the tasks to be performed as outlined in the applicable manuals.

Evaluator's comments: ____

____

____

____

Introduction to Microprocessors
Unit 2

Job Sheet 5—Troubleshoot Microprocessor Circuits

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	Rating
• Troubleshooting procedure was well designed	________
• Equipment was used correctly	________
• Correct problems were identified	________
• Problems were correctly repaired	________

Introduction: For this job sheet, your instructor will provide you with a microcomputer that has one or more problems. Those problems may be defective components, shorts, opens, incorrect wiring, software problems, or other conditions that an electronics technician is likely to encounter in this type of circuit. Using what you have learned about troubleshooting, component testing, and microcomputer operation, you will be required to design a troubleshooting procedure for the equipment and then carry out that procedure to identify and correct problems in the computer.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Microcomputer provided by instructor
- Paper and pencil
- Equipment as required by troubleshooting procedure
- Materials as required by troubleshooting procedure

B. Procedure

☐ 1. Examine device for preliminary troubleshooting assessment.

☐ 2. Define troubleshooting procedure in writing.

☐ 3. Discuss troubleshooting procedure with instructor.

Job Sheet 5

☐ 4. Conduct troubleshooting procedure.

☐ 5. Identify problems and record results of troubleshooting.

☐ 6. Repair equipment to return to operational state.

☐ 7. Verify that repair has returned equipment to an operational state.

☐ 8. Discuss the problem and your response with your instructor.

☐ 9. Return equipment and materials to their proper storage location.

Evaluator's comments: ____

____

____

____